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Sewage Research

HIGH AND LOW TEMPERATURE DIGESTION EXPERIMENTS. III. EFFECT OF CERTAIN ORGANIC WASTES *

By Willem Rudolfs and Lloyd R. Setter

Chief and Assistant, Division of Water and Sewage Research

Studies previously recorded (1, 2) on high and low temperature digestion have shown that digestion time could be reduced, the destruction of organic matter may be greater and the rate of gas production may be accelerated when sewage solids are subjected to thermophilic conditions, as compared with low temperature or mesophilic digestion. Subjecting the solids to a primary period of high temperature digestion and a secondary period of low temperature digestion would be of practical and economical advantage.

The information available on the effects of certain trade wastes upon sludge digestion is rather meager. Still less is known about the effects of such wastes under thermophilic conditions. A fair amount of work has been done on the effect of iron wastes and iron compounds, but the influence of many trade wastes is mostly conjecture. During several years a large number of experiments have been made in our laboratory for the purpose of: (1) determining the relative effects of different trade wastes when added in quantities considered sufficient to exert definite influences on volatile matter reduction, gas production, hydrogen sulphide production, and general operation (difficulties); (2) to find roughly the limits of addition of trade wastes; (3) to compare the relative effects of mixtures subjected to mesophilic and thermophilic conditions; and (4) to find out something about the so-called "acclimatization" of digesting sludges to the different types of trade wastes added. It is intended to present results and discuss groups of wastes which may be considered as more or less representative of certain "organic" wastes, "toxic" wastes and "inert" wastes, and wastes treated with coagulants in conjunction with sewage. The results now reported were obtained mainly during the years 1930 to 1932.

Materials, Methods and Procedure

The fresh sewage solids and ripe sludges used were collected from the Plainfield, N. J., sewage treatment plant. The trade wastes were obtained from different industries by compositing samples on a typical day. The collected materials were mixed as rapidly as possible in the laboratory with the domestic sewage sludge. Materials chosen as

* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J. Division Water and Sewage Research.

representatives of organic wastes consisted of slaughterhouse (blood), dye, rug, tannery and wool wastes.

The wastes were mixed in varying quantities with fresh domestic sewage solids and the mixtures added to ripe sludge. The amounts of waste and the sources of seed material are given in the tables. The chemical composition of the wastes used is given in Table I.

Gas was collected from known quantities of mixtures, while solids and ash determinations were made during the course of digestion from other portions of the original mixtures incubated under the same conditions. In the earlier experiments the gas produced was washed in 2 per cent zinc acetate solutions, before passing into the gasometers, for determinations of hydrogen sulphide. Some difficulties were encountered with the H_2S collections. The H_2S in the gas generated reacted with the zinc acetate and precipitated on the walls of the delivery tubes. The precipitate was dissolved in iodine solutions. The acetic

TABLE I.—*Composition of Trade Wastes*

Material	Solids	Ash	Ox. Cons. 30 min.	Alkalinity
	%	%	p.p.m.	p.p.m.
Blood *	20.1	2.56	1,880	—
Dye waste	0.54	86.5	190	3,000
Rug waste	0.468	84.0	250	—
Tannery vats	1.475	29.6	1,290	620
Tannery composite	0.876	81.8	430	500
Tannery lime wash	—	—	60	13,600
Wool waste †	2.864	1.012	5,500	5,200

* B.O.D. 7,200 p.p.m.

† The wool waste contained in p.p.m. 11,700 grease, 1,210 soaps, ammonia 156, sulphides 8.7, sulphates 632, chlorides 375, suspended solids 1,200, vol. susp. sol. 936.

acid liberated by the precipitate of zinc sulphide volatilized to a considerable degree and decomposed the rubber stoppers of the H_2S wash bottles. At intervals the zinc acetate-zinc sulphide solutions were made acid with hydrochloric acid in the presence of an excess of iodine. The excess was titrated with 0.02 *N* sodium thiosulphate and the iodine demand calculated as H_2S. These H_2S determinations are not considered accurate and have been included only in those cases where no further calculations were made.

In the later series of experiments the hydrogen sulphide in the gas was absorbed in 0.02 *N* slightly acid iodine solutions. The difficulties with the zinc acetate absorption were eliminated, but very small amounts of iodine volatilized, which were compensated for by very small quantities of H_2S escaping from bubbles of gas passing through the iodine solutions. Undoubtedly, any unsaturated hydrocarbons present could consume iodine, but apparently the amounts were very small, if any. Total solids and ash determinations were made after

0, 10, 30 and 60 days, while gas production was measured daily and the gas was analyzed from time to time.

Results

The large number of mixtures used for the purpose of determining the limiting quantities of wastes and the subsequent mass of results obtained prevent the presentation of all the material. An effort has been made to select groups of mixtures which could be used as examples, in addition to specific mixtures which indicate the general behavior of the wastes. Whenever results of several mixtures showed that the quantities of waste were excessive, the results are not shown unless a certain point needed illustration. In those instances where the quantities of waste were less than could be tolerated the results have been omitted when the results of the maximum quantity of waste added were sufficient to show the general behavior. This method of presentation may sometimes result in statements which are not wholly supported by the results given, but which are based upon all results obtained.

The results presented have been divided into three sections, namely: (1) additions of trade waste to sludge mixtures kept at 20° C. (mesophilic digestion), using ripe sludge as collected; (2) similar additions of wastes to ripe sludge produced in previous experiments (acclimatization); (3) additions of wastes to thermophilic sludge.

A. Effect on Mesophilic Digestion

Some of the results obtained are presented in condensed form in Table II where the volatile matter reduction, gas production and hydrogen sulphide formation are shown, after definite periods, for several concentrations of wastes added to fresh solids-ripe sludge mixtures. The gas production after definite periods of incubation of some other mixtures, together with the volatile matter reduction and hydro-

Table II.—*Summary of Analyses*

No.	Waste Added	On Basis of Fresh Solids Volume	On Basis of V.M. in Fresh Solids	V.M. Begin.	V.M. Red. after 10 Days	V.M. Red. after 30 Days	Gas/gr. V.M. Added after 30 Days	V.M. Red. after 60 Days	Gas/gr. V.M. Added after 60 Days	H_2S Prod. as S	pH Begin.	pH End
		%	%	%	%	%	c.c.	%	c.c.	mgm.		
10	Control	0	0	3.35	15.5	34.6	460	34.5	650	0.41*	6.8	7.8
8	Blood	50	40.5	7.21	47.0	57.6	210	57.8	221	29.80	7.2	7.6
9	Blood	100	81.6	11.90	42.0	56.7	164	—	168	63.60	7.0	7.6
21	Tannery vat	10	9.75	2.60	4.2	31.5	475	34.6	700	0.79	6.8	7.4
22	" "	20	21.0	2.53	5.8	25.3	480	30.8	761	1.74	6.8	7.6
23	" "	50	57.0	2.14	4.8	12.3	69	12.7	150	—	6.8	7.4
31	Tannery composite	10	9.75	2.67	13.1	33.0	400	37.6	445	—	6.8	7.6
32	" "	20	21.0	2.44	12.8	32.8	235	34.0	297	1.37	6.8	7.6
33	" "	50	57.0	2.24	—	32.5	0	36.0	5	—	6.8	7.6
41	Tannery lime wash	20	20.2	2.46	11.7	31.0	380	35.4	514	1.87	7.8	7.8

gen sulphide production for the whole period of digestion are shown in Table III.

In the instances where weighed amounts of slaughterhouse waste, tannery vat, tannery composite and tannery lime wash were added, the gas production per gram of volatile matter added decreased with increasing quantities of wastes. This was not the case when wool scouring and rug wastes were added. At the end of the experiments the two latter mixtures produced larger quantities of gas when more waste was added.

For convenience, the different sludge-waste mixtures are briefly discussed separately.

Tannery Waste.—Volatile matter reduction, after 30 and 60 days digestion of the tannery vat waste, decreased with increasing quantities of waste added. This was not the case when lime was present either in the form of lime wash or in the composite. The cumulative gas production shown for the different mixtures in Fig. 1, indicate that larger quantities of tannery waste had an appreciable depressing ef-

TABLE III.—*Gas Production, Volatile Matter Reduction and H_2S Production*

No.	Waste Added	Waste by Volume	Gas after			Vol. Mat. Red. (87 Days)	H_2S as S	H_2S	H_2S in Gas (Volume)
			20 Days	30 Days	87 Days				
		%	c.c.	c.c.	c.c.	%	mgm.	c.c.	%
40	None	0	524	665	754	45.6	3.20	4.57	0.6
81	Wool scouring	10	415	620	750	43.3	3.14	4.50	0.6
82	" "	20	93	600	753	44.8	15.60	22.30	2.9
91	Rug dye	10	343	629	883	47.4	3.20	4.57	0.6
92	" "	20	270	339	656	46.8	19.80	28.30	4.3

fect. Quantities of tannery vat wastes up to 20 per cent by volume actually stimulated gas production somewhat, but the larger quantities reduced the rate as well as total gas production. Most pronounced was the effect of the tannery composite. With the tannery vat waste there was a general relationship between volatile matter reduction and gas production, but this was not the case when the lime wash or composite were added in different quantities. The tannery composite wastes affected gasification greatly, but not the volatile matter reduction. After about 35 to 40 days the percentage volatile matter reduction was the same as for the controls, but with increasing quantities of waste added, gas formation was prevented. The composite seemed to contain substances which inhibited the activities of gas-forming bacteria, but not the liquefying organisms. The smaller quantities of tannery vat waste, which did not contain residues from the rest of the factory, stimulated gas formation slightly after continued incubation, probably on account of decomposition of a part of the organic waste added, but had a retarding effect upon volatile matter reduction. Di-

gestion of mixtures with the addition of tannery composite up to 14 per cent by volume produced as much or more gas than the control, although the volatile matter had not been reduced to the same extent. On account of the great number of mixtures used only a part of the results are given to indicate tendencies.

Not until 20 per cent of lime wash by volume was added was a retarding effect on gas formation noted. With larger quantities the pH values of the mixtures at the beginning of the digestion period were 8.0 or above, or considerably out of the range for optimum digestion of

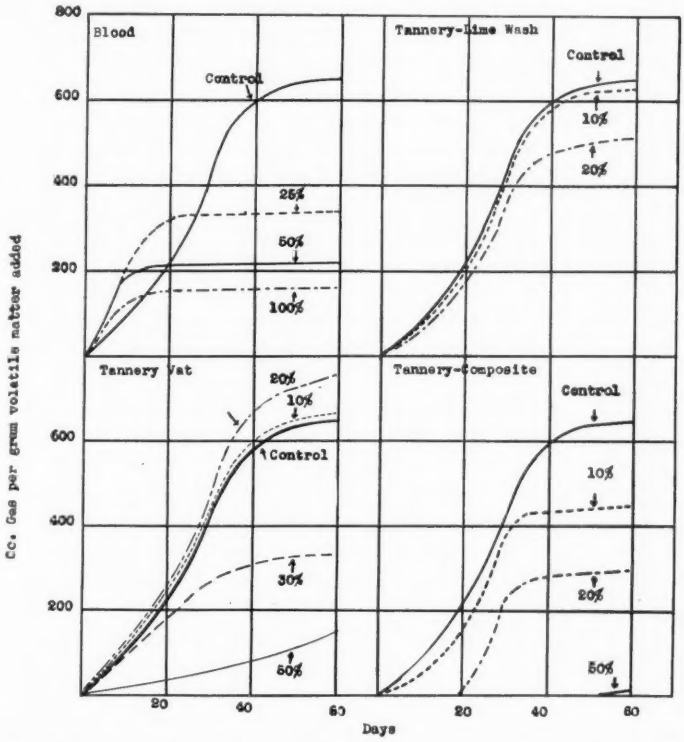

FIG. 1.—Cumulative gas produced from various sludge-tannery waste mixtures digested under mesophilic conditions.

the sludge mixtures used. The effect on volatile matter reduction was much less pronounced. With 20 per cent addition, volatile matter reduction was somewhat retarded during the first 30 days, but was practically the same after 60 days of incubation.

The question arises why the tannery vat waste retarded volatile matter destruction and gas formation, whereas the tannery composite affected gas production but not the destruction or liquefaction of the fresh solids. Since the larger amounts of lime waste retarded gas production but not the decomposition of the volatile matter a part of

the retardation in gas formation of the composite might have been caused by the lime wash, while the neutralization effect of the lime would help the volatile matter destruction. It is a well known fact, and borne out again in these experiments, that excessive quantities of lime retard or may even prevent gas formation. Liquefaction, on the other hand, may be stimulated, similar to the stimulation of liquefaction by acidic materials or acids. The change of complex organic materials to less complex substances by the process loosely defined as liquefaction, when excessive quantities of alkalies or acids are present, appears either to be different from the breakdown processes in the absence of chemicals, or else it may cause intermediate decomposition products to be temporarily or permanently fixed, so that they resist conversion into gaseous form. The temporary partial stabilization or fixation of the organic intermediate decomposition products results in retardation of gas formation, shown by an increase in digestion time, whereas the more permanently fixed materials seem to prevent gas production. Permanent fixation would not take place when acids or alkalis are added, although the digestion time would be increased so greatly that for practical purposes it could be considered as permanent. Fixation of intermediate products with chemicals, so that the product formed would resist stabilization by gasification (which may result from excessive additions of iron salts) under anaerobic conditions could be considered permanent. When such fixed materials are submitted to aerobic conditions, different organisms and a different mode of gasification may result.

The effect of tannery wastes on hydrogen sulphide production was comparatively slight or negligible.

Blood Waste.—The blood waste was readily decomposed and did not seem to affect greatly volatile matter reduction of the fresh sewage solids. The effect on gas production was material. Whereas the control produced 1330 c.c. of gas per gram of volatile matter destroyed, a 40 per cent blood addition produced only 365 c.c. and an 80 per cent blood addition 289 c.c. of gas per gram of total volatile matter destroyed. Even with 25 per cent blood added, gas production was greatly reduced, although an initial stimulation occurred. Apparently the blood itself did not produce gas, or if so, the addition of blood retarded gas production from the original fresh solids to such an extent that the ultimate result was less gas than from mixtures receiving no waste. Calculations seem to show that the addition of blood actually retarded gas production from the fresh solids added. This can be seen from the following figures showing the gas produced per gram of volatile matter added as fresh solids:

Days	Blood 40%	Blood 80%	Control
30	296	295	460
60	311	312	650

In spite of the lower gas production the blood waste added caused violent foaming of the mixtures. This type of foaming was different from that frequently encountered in digestion units where acidic foaming is most prevalent. The acid foaming is usually the result of excessive activity of carbon dioxide producing bacteria, and in the presence of some undecomposed or partially decomposed fats, a mass of small gas bubbles is produced surrounded by a film of fats or fatty acids, resulting in a froth. In the instances under discussion there was no acid foaming. The rapid disintegration of the blood resulted in the production of considerable ammonia. The ammonia formed, together with the other gases produced from the fresh solids, was prevented from escaping rapidly and easily on account of the greasy material present. It is readily seen that under such conditions foaming would occur and that the addition of lime would have aggravated the foaming condition.

The gas produced was extremely offensive. The amounts of hydrogen sulphide present in the gases produced were high, namely more than 3 per cent with the lower addition of blood and over 6 per cent with the higher quantity given in the table. The large quantities of hydrogen sulphide alone would give a disagreeable odor to the gas, but in the presence of the ammonia the gas became very pungent and offensive. The offensive odor was not confined to the gas, but was also present in the sludge and supernatant liquor. After a digestion period of 50 days the supernatant liquor had still a very offensive odor.

Wool Scouring Waste.—A portion of the results obtained on wool scouring waste, dealing with gas production, volatile matter reduction and H_2S production are shown in Table III. After a digestion period of 87 days the percentage volatile matter reduction of the mixtures was about the same as of the control. The results obtained for shorter digestion periods are substantially the same. Plotting the gas produced per gram of volatile matter added (Fig. 2) shows that there was some retardation, particularly up to the 20th day of digestion. The retarding effect increased with the volume of waste added. Although digestion was practically completed after 40 days, the experiments were continued to determine whether the wool waste would produce additional gas. This was apparently not the case. The peak of daily gas production from the mixture to which 10 per cent waste was added came about 6 days later than the control and from the mixture receiving 20 per cent waste about 10 days later.

With the smaller quantities of waste added, hydrogen sulphide formation was the same as from the control. This is of interest when the comparatively large quantities of sulphates present in the wool waste are taken into consideration. Apparently the addition of 60 p.p.m. sulphates was of no importance, but when double the amount was added the H_2S production increased greatly.

The addition of about 20 per cent of the wool scouring waste, containing large quantities of grease and soaps, was about the maximum tolerated.

Rug Dye Waste.—After a digestion period of 87 days the volatile matter reduction of the mixtures containing dye waste was slightly higher than of the control. For shorter digestion periods the percentage volatile matter reduction was only slightly less. The rate of gasification was materially slower, especially during the first 20 days of incubation. At the peak of daily gas production for the control the mixture to which 10 per cent dye waste was added had produced about 35 per cent less gas, and the mixture with 20 per cent waste had produced 50 per cent less gas. With continuation of digestion, after the controls were practically completed, the mixture with 10 per cent waste produced eventually more gas per gram of volatile matter added. A change from initial retardation to a greater production of gas occurs frequently when chemicals or wastes are added, which may act as

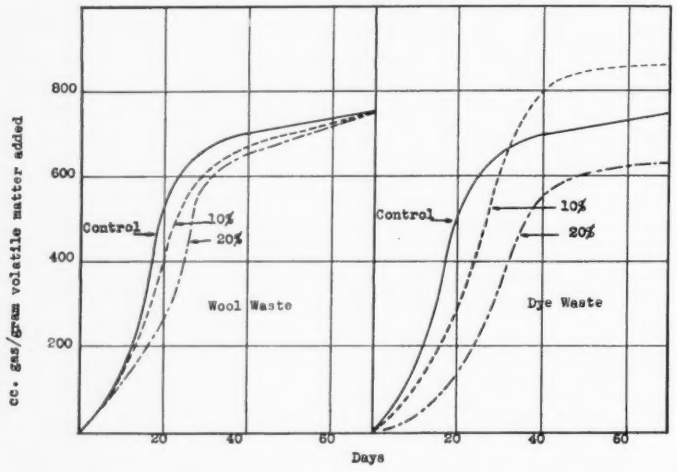

FIG. 2.—Cumulative gas produced from sludge to which dye and wool wastes were added.

coagulants or precipitants, or when substances are present which require biological adjustment before the waste can be destroyed or the coagulated materials further decomposed.

ACCLIMATIZATION

In addition to the wastes tested in the experiments described above, similar wastes were added to determine the effect on the digestion of fresh solids in conjunction with the possibility of acclimating the microorganisms to a particular waste. If on repeated additions, using as seed the ripe sludge produced previously when the same quantity of waste was added, the observed retardation was reduced or overcome, a tendency to acclimate would be indicated. This process could be tested further by trials in which necessarily larger quantity of the same wastes were added. If in such cases less retardation was observed the

possibility of greater additions without deleterious effects would be demonstrated. The method of testing was briefly as follows: Ripe sludge obtained in digestion with 20 per cent tannery vat waste (No. 22) was used as seed for fresh solids receiving 40 per cent tannery vat waste. This procedure was then repeated with larger amounts of waste added. In the cases where semi-digested sludge had been produced, or where retardation was material, the resulting tannery waste-sludge mixture (No. 32) was used as seed and buffer for fresh solids containing the same quantity of tannery composite waste (20 per cent by volume). This procedure was then repeated until the digestion time and gas production was similar or equal to the controls. If on repeated trials the results did not show material difference from the original mixtures the experimentation was stopped. In all instances the fresh solids-ripe sludge mixtures were made on the basis of a 2 to 1 ratio of volatile matter. The volatile matter in the wastes was neglected when only small quantities were present.

Results

Some of the results obtained with specific mixtures are given in Table IV. If other mixtures or different wastes behaved dissimilarly the facts are mentioned in the text.

Table IV.—*Seed Used, Total Gas, Volatile Matter Reduction and H_2S Production*

No.	Waste Added	Waste in Mix.	Seed from	Gas after Days			Vol. Mat. Red. (87 Days)	H_2S as S	H_2S in Gas	Ratio W. : F.S.* : R.S. (by Volume)
				20	39	87				
		%		c.c.	c.c.	c.c.	%	mgr.	%	
40	None	0	Plainfield	524	665	754	45.6	3.2	0.6	0 : 1 : 1
224	Tannery vat	40	No. 22, 20% waste	343	696	874	37.3	8.6	1.4	0.66 : 1 : 1.2
311	Tannery comp.	10	No. 31, 10% waste	589	694	785	43.2	4.5	0.8	0.12 : 1 : 1.1
322	" "	20	No. 32, 20% waste	619	755	828	46.0	8.9	1.6	0.25 : 1 : 1.2
412	Tannery lime wash	30	No. 41, 20% waste	634	707	786	47.5	17.4	3.1	0.43 : 1 : 1.2

* Fresh solids less than 24 hrs. old, unlimed.

The sludge mixture receiving 20 per cent tannery vat waste gasified in the previous experiments at about the same rate as the controls, while near the end of digestion the rate of gas production was maintained longer, so that total gas production per gram of volatile matter added was greater than from the control. With larger additions of waste there was distinct retardation. Using the sludge of the mixture to which 20 per cent waste had been added as seed and increasing the amount of the same waste to 40 per cent by volume, the rate of digestion was decreased during the first 15 days, followed by a much faster rate which resulted in 15 per cent more gas after 60 days incubation. The

cumulative gas production curves in Fig. 3 show more clearly that no retardation occurred with 20 per cent tannery vat waste, but there was some retardation when the volume of waste was increased to 40 per cent. A mixture containing 30 per cent vat waste, to which ordinary ripe sludge had been added instead of sludge produced during previous digestion, resulted in a considerable retardation. For comparison, the cumulative gas production from this mixture is given, designated by the curve 30 per cent (ordinary). Successive inoculation with digested sludge-waste mixtures of the same character increased the rate and total gas production until the rate and amount were equal to the control. Addition of about 40 per cent vat waste appeared to be the limit from the standpoint of digestion time.

The tannery composite waste added in quantities of 10 and 20 per cent retarded digestion materially, as indicated by the gas curves in

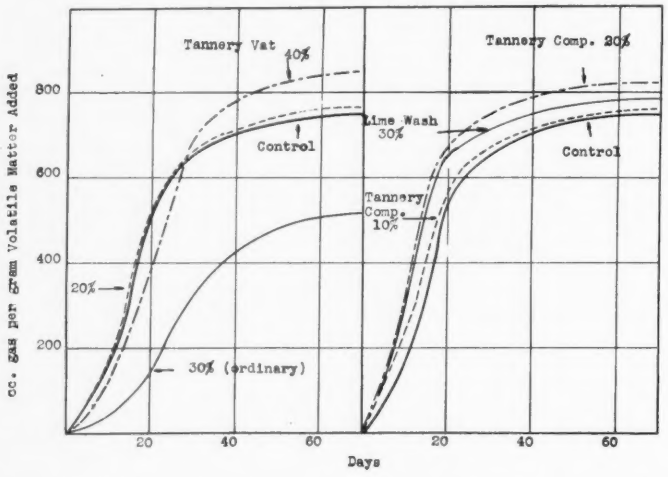

FIG. 3.—Gas production from "acclimated" sludges to which varying quantities of waste were added.

Fig. 1, but when seed produced from previous batches receiving the same waste was utilized, some stimulation in gas production occurred, while the volatile matter reduction was about the same as of the controls. Since volatile matter reduction was not retarded in the previous mixtures, it would appear that liquefaction had occurred. When the mixtures were seeded with material in which the gas-forming flora had re-established itself, gas production became normal. All experiments related thus far indicate that the wastes affected gas-forming organisms first, and only with excessive quantities was the growth of liquefying organisms retarded.

When tannery lime wash waste was added amounting to 20 per cent by volume of the fresh solids present, it was observed that digestion proceeded rapidly; as much volatile matter was destroyed as in the controls, but the total gas production per gram of volatile matter added

was less. When the sludge produced with 20 per cent lime wash addition was used as seed material for fresh solids containing 30 per cent lime wash, digestion proceeded at a more rapid rate than the control. After 20 days digestion practically the same quantity of gas was produced as during 29 days digestion of the control. At the end of the experiment the mixture with 30 per cent lime wash had produced somewhat more gas per gram of volatile matter added. Addition of 40 per cent lime wash resulted in a slight retardation, even with repeated re-seeding, indicating that an addition of 30 per cent constituted the approximate limit.

Discussion

Various trade wastes added to the digesting fresh solids-ripe sludge mixture exerted a retarding influence only when comparatively large quantities were added. With small quantities, any retarding effect was noticed first in gas production. The organisms responsible for liquefaction were apparently less affected than those producing gas. In some cases an increase in volatile matter destruction was indicated. This apparent reduction of volatile matter occurred when the materials were liquefied to a larger extent than gasified. Much of this liquefied material was destroyed and lost on drying for solids determination. It should be remembered that where "acclimatization" is indicated the gas produced in excess of the controls may be caused by the gasification of less stable volatile matter of the ripe sludge used as seed material, or it may be due to the gasification of liquefied volatile matter present. Although the liquefied material gives rise to gas, the current method of dry solids determination would not necessarily show its presence.

When trade wastes were added in comparatively large quantities, the hydrogen sulphide in the gas evolved was increased. It is natural to expect that with increased liquefaction the H_2S production should increase. The results seem to show that the occasional presence of trade wastes tends to increase H_2S production to a greater extent than when such material is received continuously. As examples the following may be cited:

Mixtures Seeded with Ripe Sludge		Mixtures Seeded with Ripe Sludge from Sludge-waste Mixtures	
	H_2S as S Mgr.		H_2S as S Mgr.
Tannery vat (20%)	1.74	Tannery vat (40%)	0.30
Tannery comp. (20%)	1.37	Tannery comp. (20%)	0.16
Tannery lime (20%)	1.87	Tannery lime (30%)	0.35

With small quantities of waste the H_2S production was greater, when fresh solids-waste was mixed with ripe sludge, than from larger quantities of waste seeded with sludge which had previously received waste of the same nature. It seems, therefore, that in this respect the flora was adapted to the conditions.

The possibility of adjustment or acclimatization of a particular waste is of considerable importance for plants receiving trade wastes continuously in more or less large quantities. It is clear that the larger the quantities of waste the greater the effect will be, and the longer it will take for a sludge mixture to adjust itself to the changed conditions. Similarly, the greater the quantity of waste received, the more severe will be the effect on the rate of digestion, the gas production and time required for improvement, or in other words the digestion capacity required.

To illustrate these points a few of the mixtures experimented with have been chosen as examples. Although gas production is not in all cases the best and only index of digestion, a change in the rate and volume produced gives a good picture. In Table V comparisons are made between the total quantities of gas produced per gram of volatile matter of fresh solids added to ripe sludge and the gas produced on the same basis by the "acclimatized" sludge which had been digested

TABLE V.—*Increase (+) or Decrease (−) in Gas Caused by Waste With and Without "Acclimated" Seed Sludge*

Waste Added	Waste to Ripe Sludge	Gas	Waste to Acclimated Sludge	Gas
	%	%	%	%
Tannery vat	20	+15	20	+11
	30	−10	30	+12
	40	−45	40	+15
	50	−74	50	−52
Tannery composite	10	−31	10	+ 4
	20	−54	20	+15

previously with quantities of the same waste. Gas production is shown as the percentage increase or decrease over the controls. With addition of waste to the acclimated sludge the percentage gas production was increased. In the majority of cases the gas production was changed from less than that produced by the controls to more than the quantity evolved. In several instances there were still material reductions of gas as compared with the controls, indicating that too large quantities of waste were detrimental to the digestion processes to such an extent that repeated efforts of acclimatization failed. There appears to be a limit to which organic wastes can be added even with continuous operation and careful control. This limit is, however, substantially higher when the waste is received continuously than when intermittent batches are discharged. In general, considerable quantities of waste can be tolerated, provided they are received regularly, but chances that gas production will be interfered with or will become irregular are increased, while the wastes may produce unusual quantities of odor.

B. Effect on Thermophilic Digestion

Thermophilic seed sludge used in the first series of experiments was produced in the laboratory from fresh solids seeded on a 2 to 1 ratio of volatile matter of fresh solids and ripe sludge. To mixtures of this thermophilic sludge and fresh solids, varying quantities of wastes were added and the mixtures were incubated at 50° C. At the beginning of the experiments, and at intervals during digestion, solids, ash and pH determinations were made. During digestion total gas was measured and hydrogen sulphide was fixed. The most reliable method of H_2S fixation was found to be by passing the gas through zinc acetate solution in 10-bulb absorption flasks placed outside the incubators.

The results of solids and determinations of the materials and a number of the mixtures used for discussion are shown in Table VI. A number of mixtures, with quantities of wastes added less than those

TABLE VI.—*Thermophilic Digestion. Solids, Ash, and pH Determinations at Beginning*

	Solids	Ash	pH
	%	%	
Thermophilic sludge	2.27–2.96	40.1–43.6	7.9
Fresh solids	6.40–6.50	21.6–22.2	6.4
Wool scouring waste	2.86	35.3	9.2
Rug waste	0.47	84.0	7.6
Tannery waste	0.90	81.8	8.0
T.S.–F.S.	2.86	41.8	7.2
T.S.–F.S.—Wool, 10%	2.64	41.8	7.3
T.S.–F.S.—Wool, 20%	2.69	42.5	7.4
T.S.–F.S.—Rug, 10%	2.53	42.0	7.3
T.S.–F.S.—Rug, 20%	2.31	41.2	7.3
T.S.–F.S.—Tannery, 10%	1.88	39.9	7.3
T.S.–F.S.—Tannery, 20%	2.44	38.0	7.3

given in the table, produced practically similar results as those recorded. Several other types of waste used in the experiments behaved in accordance with their composition in a similar way to those presented and the recording would serve no useful purpose other than duplication of the results given. Since the results given are in the nature of "type" results general statements made in the discussion are based upon the findings of all the experiments.

RESULTS

The results on three types of wastes added in different concentrations are summarized in Table VII. From the volatile matter reduction and total gas production figures it is evident that quantities of waste up to 10 per cent had no effect. A slight retardation is noticed with 20 per cent additions, by volume, of the wool and tannery waste, while retardation was more evident with 20 per cent rug waste.

TABLE VII.—*Summary of Results of Thermophilic Digestion after 27 Days*

No.	Waste Added		Solids Reduction	Vol. Matter Reduction	Gas/gr. Vol. Matter Added	Gas/gr. Vol. Matter Destroyed	pH at End
	Type	%	%	%	c.c.	c.c.	
80	None	0	28.5	41.0	490	1190	7.9
81	Wool	10	29.2	41.3	504	1215	8.0
82	Wool	20	28.8	41.5	484	1163	7.9
91	Rug	10	28.2	40.5	525	1300	7.8
92	Rug	20	29.3	40.0	344	903	7.6
311	Tannery	10	30.6	41.0	522	1275	8.2
322	Tannery	20	25.6	32.1	465	1470	7.9

Although the results obtained after 27 days digestion indicate that there was no appreciable difference in volatile matter reduction and gas production when the waste mixtures are compared with the controls, this does not show whether there were lag periods or whether some of the waste mixtures digested at a more rapid rate than the controls. The time required for the controls to produce 90 per cent of the total gas evolved was 17 days, while the peak of gas production came after 11 days incubation. In order to indicate early stimulation of gas production by some of the waste materials added, as well as to compare the time required for reaching the peak of gas production and the elapsed time to produce equivalent amounts of gas as in the controls, the figures in Table VIII are significant. Gas production

TABLE VIII.—*Time Required for Gas Production*
(c.c. Gas per Gram Volatile Matter Added)

Waste Added	Peak of Gas Prod.	To Produce 90% of Total Gas	To Produce Equal to Controls 90%
Controls	11	17	17
Wool, 10%	10	14	13
Wool, 20%	11	17	17
Rug, 10%	11	17	15
Rug, 20%	23	25	27
Tannery, 10%	9	13	11
Tannery, 20%	9	16	19

from mixtures receiving the small quantities of wastes was stimulated during the first few days and required the same or less time to reach the peak. The most interesting figures are perhaps those showing that the time required to produce quantities of gas equal to 90 per cent of the total gas produced by the controls was less when not more than 10 per cent of waste was added. Increasing the quantities to 20 per cent required the same or longer time for digestion. These and other results seem to indicate that thermophilic sludge is capable of handling moderate quantities of organic wastes, will produce as much gas as

from sludge without waste in a shorter time, without being "acclimated."

Acclimated thermophilic sludge behaved very similar to acclimated mesophilic sludge. The quantities to be added could be increased to 20 and 30 per cent, depending upon the type of organic waste added. Since presentation of the results would be in effect a repetition of the results given under mesophilic digestion, the results are omitted from this paper.

In all cases the gas collected during the first day of incubation under thermophilic conditions included the gases evolved by expansion resulting from heating the air and mixtures from 20° to 50° C. The quantities of gas evolved during the first day from the different mixtures varied from 13 to 20 c.c. per gram of volatile matter added. These quantities are of little importance since they amount to less than 5 per cent of the total gas production and come within the limits of individual variations.

It is of greater interest to compare the composition of the gases produced by the different mixtures. Gas analyses made at approximately the peak of gas production showed that the carbon dioxide contents of the mixtures to which waste was added were somewhat lower than from the controls. The methane content of the gases produced by the controls varied from 67.7 to 70.0 per cent, whereas the content in gas from the mixtures receiving various kinds and quantities of wastes varied from 69.2 to 74.8 per cent.

Comparison of Mesophilic and Thermophilic Results

It is of interest to compare the composition of the gases produced under thermophilic conditions with those produced from mesophilic sludge. The gas production per gram of volatile matter at the peak of gasification, and the carbon dioxide content, for mixtures receiving similar quantities of wastes, are compared in Table IX. A comparison of the CO_2 content of the gas produced at lower temperature shows

Table IX. *Carbon Dioxide Content of Gas Produced Under Thermophilic and Mesophilic Conditions*

Waste Added	Thermophilic		Mesophilic	
	Total Gas at Peak	CO_2	Total Gas at Peak	CO_2
	c.c.	%	c.c.	%
None	233	25.0	407	22.4
Wool, 10%	305	21.4	—	—
Wool, 20%	303	22.2	507	21.0
Rug, 10%	323	22.3	243	26.4
Rug, 20%	275	22.6	423	22.0
Tannery, 10%	348	21.1	470	21.4
Tannery, 20%	250	21.9	411	22.3

little variation as compared with the controls. In the case of gas produced under thermophilic conditions the CO_2 content was somewhat lower when wastes were added. Comparison of the CO_2 content of the gas produced at lower temperatures with that produced at higher incubation temperatures, at the times when the largest quantities of gas evolved, shows only slight variations. The heating value of the gas produced under the different temperature conditions appears to be practically the same.

The time required to reach the peak of gasification and to complete digestion (90 per cent of the total gas produced) was shorter for all mixtures under thermophilic conditions, but the total gas production from the acclimated mesophilic sludge was greater than from the non-acclimated thermophilic sludge. Acclimation of the thermophilic sludge allowed the addition of greater quantities of waste material, caused the production of more gas in a shorter time than from non-acclimated thermophilic sludge, but produced in all cases somewhat less gas per gram of volatile matter added, as compared with acclimated mesophilic sludge.

Some results obtained are shown in Table X, illustrating this point.

TABLE X.—*Comparison of Gas Production from Mesophilic and Thermophilic Sludge-Waste Mixtures*

Mixture	Mesophilic (Acclimated)			Thermophilic (Non-acclimated)			Thermophilic (Acclimated)		
	Gas after:			Gas after:			Gas after:		
	20 Days	40 Days	When 90% of Controls was Prod.	15 Days	20 Days	When 90% of Controls was Prod.	10 Days	15 Days	When 90% of Controls was Prod.
	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
Controls	523	696	679	410	456	437	417	462	445
Wool, 10%	—	—	—	467	494	480	510	594	562
Wool, 20%	252	686	638	412	470	441	498	522	507
Rug, 10%	264	759	642	445	510	471	574	602	582
Rug, 20%	270	808	714	87	163	107	370	590	562
Tannery, 10%	588	717	703	496	516	503	548	680	644
Tannery, 20%	619	778	764	408	450	425	532	692	680

Acclimated mesophilic sludge, to which 10 per cent of rug waste was added, produced after 40 days digestion a total of 759 c.c. of gas per gram of volatile matter, as compared with 574 c.c. produced in 10 days from acclimated thermophilic sludge. Stating it differently, the time required to produce 90 per cent of the gas under mesophilic conditions was in this instance 34 days and under thermophilic conditions 11 days. The figures given for gas production at the time when 90 per cent of the gas was produced from the control mixtures indicates the relative retarding or stimulating effect caused by the wastes added. The time

required to produce volumes of gas equal to 90 per cent of the controls was materially greater under mesophilic conditions, and the longer time required for complete digestion was evidently caused by the initial lag period when wastes are added. Such a lag period was much less pronounced under thermophilic conditions.

Effect of Wastes on Dewatering

In order to determine the effect of the addition of different trade wastes on the dewatering of the resulting digested sludge, series of tests were made to compare amounts of liquids which could be removed under standard conditions without the addition of coagulating or conditioning agents. Equal quantities of sludges were vacuum filtered at the end of the respective digestion periods. The filters were standardized against an Oliver filter and operated for 30 minutes with 21 inches pressure. The amounts of filtrate were measured at short intervals to enable the plotting of rate curves.

Condensed results, showing the amounts of filtrate after 5 and 30 minutes, together with the color and pH of the filtrate and the percentages of solids and ash of the thermophilic digested sludges, are shown in Table XI. The results show that with the exception of large quantities

Table XI.—*Quantities of Filtrate Obtained from Thermophilic Digested Sludge-Waste Mixtures (Average of 3 Samples)*

Waste Added	Filtrate		Color of Filtrate	Solids	Ash	pH Filtrate
	5 min.	30 min.				
	c.c.	c.c.		%	%	
None	27	150	Black	2.66	44.8	7.5
Wool, 10%	28	94	Yellow-blk.	3.32	45.0	7.9
Wool, 20%	15	83	Black	3.06	45.8	7.9
Rug, 10%	29	103	Pale yellow	2.94	45.4	7.7
Rug, 20%	8	56	Slight yellow	2.76	44.7	7.7
Tannery, 10%	10	78	Yellow black	2.48	44.5	7.7
Tannery, 20%	71	81	Slight yellow	2.28	45.3	7.6
Tannery, 40%	32	172	Black	2.34	41.4	7.4
Tannery lime, 20%	26	200	Yellow black	2.38	47.7	7.6

of tannery waste and moderate quantities of tannery lime waste, dewatering of the sludge-waste mixtures was poorer than of the controls. In the case of the 40 per cent tannery waste, digestion was greatly retarded. In general, it appears that with the increase in the quantity of trade waste, the dewatering and drying of the digested sludges was adversely affected. Similar results, but less marked, were obtained with sludge-waste mixtures which were digested under mesophilic conditions.

Odor Production

Hydrogen sulphide in the gas varied under thermophilic condition from 0.01 to 0.4 per cent. This compares with 0.06 to 2.7 per cent found in the gas formed under mesophilic conditions. It appears that the wastes had considerably less effect on hydrogen sulphide production, when digested with sewage sludge under thermophilic conditions, than on sludge incubated at lower temperatures. The fact that less hydrogen sulphide was present in the gas does not necessarily mean that the odor from the digesting mixtures and the ripe sludge was less, because other odors may take their place, or those present may be intensified. Although as a rule under ordinary conditions the odors from sulphur compounds constitute about 90 to 95 per cent of the total odors produced, the degradation products from nitrogenous substances may play a role.

It was impossible to determine in any satisfactory way the intensity of the mixtures of odors produced during digestion of the different mixtures, because the character and nature of the odors changed or varied with the type of waste added. For these reasons, observations of the sludges were made during digestion and after the series of experiments were terminated and recorded rather loosely in table form to give, in a crude way, some idea of the odors emanating from the different mixtures. Only the description of odors made at the end of the experiments are given. The wording of the observations indicate that with the exception of slaughterhouse waste the odors of the ripe sludge produced under mesophilic conditions did not vary greatly from the ordinary well digested sludge. The slight ammoniacal odor, which is pungent but not offensive, accentuates the tarry gas odor of the ripe sludge and with increasing strength masked this odor. In the case of thermophilic digestion the ripe sludge odor of the controls was more pronounced than the mesophilic sludge, chiefly due to ammonia compounds causing the sludge to smell like warm barnyard manure. This pungent odor becomes offensive when other nitrogenous odors are present such as indole or skatole, and becomes extremely offensive when sulphur compounds such as mercaptans (designated as onion and pig pen odors) are present. On account of the higher temperature of the sludge these odors are noticed to a greater extent from the thermophilic sludge. In general the intensity of the odors checked with the quantities of hydrogen sulphide found in the gases produced by the mixtures.

Supernatant Liquor

Experiments conducted on the treatment of supernatant liquor produced by the mixtures digested at high and low temperatures will be recorded in a subsequent paper.

Summary and General Conclusions

Laboratory experiments were made on a large number of sewage sludge and organic trade wastes mixtures at high and low temperatures. The purpose was to determine the relative effects of different trade wastes added in varying concentrations on (1) digestion time, (2) gas production and gas composition, (3) odors, (4) drainability, and (5) the possible "acclimating" of sewage sludges to definite wastes. The different mixtures were incubated at 20° C. and 50° C. Solids reduction, gas production and hydrogen sulphide evolution were determined, and other relative observations made. The results reported upon include the effect of various tannery, dye, wool and blood wastes as examples of different types of wastes added.

The general conclusions drawn from the waste-sludge digestion experiments conducted at high and low temperature are:

Mesophilic.—(*a*) In a number of cases organic wastes added in different quantities caused a delay in digestion time, other wastes had no practical effect or even reduced the time required to produce innocuous, non-odorous, well-draining ripe sludge.

(*b*) Gas production was increased by smaller quantities of wastes, but retarded or slightly decreased with larger quantities.

(*c*) Additions of waste caused in all instances increased hydrogen sulphide concentration in the gas, which leads to increased corrosion in the gas lines and burners. The ripe sludge odor was in general affected. The type and quantity of waste added influenced the character and intensity of the odor of the resulting ripe sludge.

(*d*) Sewage sludge appears to be capable of "acclimatization" against trade wastes, thereby becoming capable of tolerating larger quantities of wastes with less detrimental effects. Continuous discharges of organic wastes are less harmful than intermittent additions.

(*e*) Ripe sludge will tolerate from 15 to 20 per cent organic waste by volume or from 15 to 20 per cent on the basis of volatile matter in the fresh solids when added intermittently, while from 20 to 40 per cent waste can be added on the same basis when the waste is received continuously.

Thermophilic.—(*a*) Sewage sludge to which trade wastes are added and digested at higher temperatures requires a shorter time for digestion than similar mixtures digested at low temperatures.

(*b*) Under thermophilic conditions sludge is less sensitive to organic trade wastes than sludge digested under mesophilic conditions.

(*c*) Sludge-waste mixtures produced slightly less gas when incubated at high temperatures, but produced 90 per cent of the possible gas in about one-third of the time as that required for low temperature digestion.

(*d*) The composition of the gas produced was similar under high and low temperature conditions, and the heat values of the gas were not materially different.

(*e*) Hydrogen sulphide in the gas produced was less than under mesophilic conditions.

(*f*) Some of the wastes had a decided effect on the odor of the ripe sludge. Odors from sludge produced under thermophilic conditions were more pronounced, chiefly due to pungent ammoniacal compounds. When organic sulphur compounds are present the odor from thermophilic sludge is more intense than from mesophilic sludge containing the same materials.

(*g*) The drainability of the sludge was adversely affected by the wastes and to a greater extent than sludge digested at low temperatures.

(*h*) Thermophilic sludge will tolerate more organic waste added either intermittently or continuously than mesophilic sludge.

TABLE XII.—*Odors of Ripe Sludges at End of Experiments*

Waste Added	Mesophilic Sludge	Thermophilic Sludge
Controls	Ripe sludge	Ammoniacal
Tannery vat, 10%	Less than controls	Less than controls
20%	Slight ammoniacal	Ammoniacal
50%	Ammoniacal	Strong ammoniacal
Tannery comp., 10%	Slight, not offensive	Slight ammoniacal
20%	" " "	Some ammoniacal
50%	" " "	Strong ammoniacal
Tannery lime, 20%	No odor	" "
Rug, 10%	Ripe sludge	Slight ammoniacal
20%	" "	" "
Wool, 10%	Ripe sludge, slight ammonia	" "
20%	" " " "	" "
Blood, 27%	Onion, very offensive	Pig pen, very offensive
55%	" " "	" " " "

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A MODIFICATION OF THE CHLORINE DEMAND TEST AND THE ORTHO-TOLIDINE TEST FOR RESIDUAL CHLORINE IN SEWAGE

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The subject of the chlorination of sewage is an important one in Buffalo; therefore the question of the applicability of the standard method for the determination of residual chlorine is of prime interest. That this test has limitations and is subject to controversy is evident from the literature.[1, 2, 3, 4] This paper discusses some of the difficulties encountered with the use of the test, and suggestions are offered leading toward improvement of the technique.

Several preliminary experiments were performed using the ortho-tolidine test. These included the following:

(1) Chlorinate sample—determine residual chlorine in 10 ml. volume.
(2) Chlorinate sample—filter and determine residual chlorine.
(3) Chlorinate sample—filter, dilute and determine residual chlorine.
(4) Chlorinate sample—dilute and determine residual chlorine.
(5) Chlorinate sample—dilute, filter and determine residual chlorine.
(6) Dilute sample —chlorinate, determine residual chlorine.
(7) Dilute sample —chlorinate, filter and determine residual chlorine.

None of these methods gave check results. It was then reasoned that if the immediate chlorine demand could be determined on a spot plate, so too could the residual chlorine be determined at the end of the contact period. This procedure was tested by chlorinating the original sample and determining the residual chlorine by spotting 1 ml. on a spot plate and adding two drops of ortho-tolidine reagent. Color gradations appeared to be easily distinguishable.

It was found that permanent color standards mixed with sewage could be read to 0.1 p.p.m. The minimum readable color (M.R.C.) in sewage appeared to be approximately 0.07 p.p.m. in very weak sewages and 0.1 p.pm. in normal to strong sewages. In extremely strong and highly colored wastes the M.R.C. might be as high as 0.3 p.p.m. For laboratory work permanent dichromate-copper sulphate color standards (0.1 p.p.m) were used beside the test spots for comparisons. The dichromate-copper sulphate standard made according to Standard Methods [5] for use in 100 ml. Nessler tubes was not used for the spot plate, but was adjusted to match the orhto-tolidine spot plate color of a chlorine solution of 0.1 p.p.m. chlorine, standardized by titration with thiosulphate. In field work it was found that the M.R.C. could be safely taken as the endpoint of 0.1 p.p.m. residual chlorine. In bright light the use of yellow colored glasses made the end point color

more easily distinguishable. Interpolations between colors can be made to determine the 0.1 p.p.m. residual, or greater amounts.

One advantage of the method is that the test can be made in artificial light. This point was checked by two different analysts on the same sample, one working in daylight, the other by electric light in a dark room. Identical results were obtained independently by the two men.

The question of the efficacy of this modification in controlling sewage chlorination was checked by numerous tests on bacterial kills in chlorinated sewage. In some 250 tests on various sewages the total bacterial kill averaged 99.4 per cent and the B. Coli kill averaged 99.3 per cent.

In spite of the good bacterial kills obtained, the low total chlorine demand obtained for Buffalo sewage in comparison with sewage of other cities led to a question concerning the accuracy of the test. A large number of chlorination experiments were run on various sewages and under varying conditions for the purpose of studying the reliability and accuracy of the test for chlorine demand. Before these are discussed however, the technique of the test as performed in the Bird Island Laboratory will be described.

The Bird Island Laboratory Chlorine Demand Test

Reagents.—(1) Ortho-tolidine made in accordance with Standard Methods [1, 5] is used.

(2) Chlorine water containing approximately 1.0 mg. Cl_2 per ml. is used as recommended.[5] For strong wastes a solution containing 5 to 6 mg. Cl_2 per ml. is used.

(3) N/40 sodium thiosulphate is used for standardization of the chlorine reagent.

Chlorine water is prepared by passing chlorine gas through an absorption train. It is stored in glass stoppered bottles. In practice the reagent is standardized at least once each hour. For special studies standardization is more frequent, but in general, hourly checks appear sufficient. There is some loss of chlorine if care is not taken to prevent aeration in adding the chlorine reagent to the burette. This is particularly true in the case of the concentrated chlorine reagent. To obviate this difficulty, a closed system is used.

Procedure.—(1) The determination must be made on a relatively fresh sample. Not more than two hours is allowed to elapse between collection of the sample and the determination of the chlorine demand. Results of determinations on composited 24 hour samples have been found to be as much as 50 per cent low when the samples are refrigerated and may be high if the samples stand at room temperature.

(2) Chlorine demand is determined on the sample at the temperature at which the sample was collected. Cold samples are not warmed to 20 degrees C. as recommended.[5] This procedure is followed because it was found that the chlorine demand varies somewhat with temperature (see below). It is believed that for sewage chlorination

control purposes, the chlorine demand should be representative of conditions actually existing in the sewer or treatment plant.

(3) Five Erlenmeyer flasks of 500 ml. capacity, containing 250 ml. (or less in the case of strong wastes) are set up. To one of these flasks is added the chlorine reagent in small quantities, usually 0.5 ml. for the initial dose and 0.2 to 0.3 ml. thereafter. After each addition one ml. is spotted on a spot plate, ortho-tolidine added, and the endpoint determined when a maximum color has developed (usually 30 to 45 seconds). When a color of 0.1 p.p.m. is observed, each of the other four flasks receive doses of chlorine water of increasing amounts of 0.1 to 0.5 ml. above the original dosage. Practice and familiarity of the analyst with the sewages helps to determine the amount of these increments. If the first flask dosage has been overrun the analyst may use dosages both smaller and larger on the other flasks. To eliminate overruns on the original immediate chlorine demand (I.C.D.) dosage, the analyst may split the first sample in half, quickly determine the chlorine demand on half, add the remaining portion of the sample, and more carefully add an amount of chlorine water calculated to give the I.C.D. This addition is based on the amount added to the first half portion.

(4) After all the flasks have received their respective amounts of chlorine water, one ml. from each flask is spotted on a plate and ortho-tolidine added. This is done as a check on the additions. Since one and one-half to two minutes have elapsed since the original addition of chlorine water, the reading obtained does not represent the immediate chlorine demand (I.C.D. about 30 sec.) but rather the two-minute chlorine demand. One ml. pipettes with large tips and rubber bulbs are used to transfer the sample from the flask to the spot plate. If marked pipettes are not used, it is convenient to remember that a shallow spot plate holds slightly more than one ml. in each spot.

(5) The amount of ortho-tolidine reagent used depends on the strength and color of the sewage. With ordinary sewages, 2 drops (0.1 ml.) are added to each ml. of sewage. This is approximately the ratio recommended by Lea,[1] (1 ml./11.5 ml.). For strong sewages, packing house wastes with blood, alkaline wastes, etc., 3 to 5 drops of ortho-tolidine are used. The extra amount of acid neutralizes alkali and tends to destroy interfering colors.

(6) It was found that a maximum ortho-tolidine color develops in from 30 seconds to one minute and thereafter fades; the stronger the sewage the more rapid the fading. This observation confirmed the findings of McCrumb and Kenney.[2] Standard Methods[5] directs that five minutes be allowed to elapse for maximum color development. Though this procedure may be proper in water chlorination, it does not seem applicable to sewage except with an extremely low chlorine demand, in cold water containing dissolved oxygen. If five minutes is allowed to elapse, it is frequently found that a sample with a higher chlorine dosage must be used to obtain a 0.1 p.p.m. residual at the five-minute endpoint. This observation is discussed in detail below.

In extremely concentrated wastes such as ammonia-still liquors and tannery wastes, it was found that solids and color present tended to obscure the ortho-tolidine color. However colors of 0.2 to 0.3 p.p.m. could be read by observing the film of water in contact with the spot plate at the surface of the liquid.

(7) After the chlorinated samples have stood for 15 minutes (*i.e.* a 15 minute contact time), they are spotted again, ortho-tolidine added, and the endpoint determined. If the proper increments of dosage have not been chosen, it is not difficult to make an interpolated color reading. If some other residual is desired, readings up to 0.5 p.p.m. are easily readable. Proper standards made for reading in 1 ml. volume must be prepared.

Though the recommended procedure [3, 5] calls for a 10 minute contact period, it was found that frequently the 15 minute chlorine demand was greater than the 10 minute and that in strong wastes the 30 to 40 minute demand was still greater. This point is discussed below.

Comparison of the Bird Island Laboratory and Standard Methods

After some 500 tests on various sewages during which the above procedure was developed it was believed advisable to make a concentrated study of the several variables in the test and its comparison to the standard method.

Accordingly sewages of various strengths from polluted river water to strong industrial wastes were subjected to an intensive study.

Triplicate analyses were made on each sample, both at the actual temperature of the sewage and at 20 degrees C. Chlorine demands were determined at the end of 2, 10, 15 and 40 to 50 minutes. In addition, the chlorine demand was determined after 10 and 15 minutes by the standard method, compensated for turbidity. Also the 10 and 15 minute and standard method readings were taken of the immediate maximum color production and the endpoint after 5 minutes contact with ortho-tolidine. To eliminate personal vagaries each of these tests was performed by a different analyst. The results of these tests are discussed below.

(*1*) *Accuracy of the Bird Island Laboratory Method.*—As might be expected, the average deviation from the mean on triplicate analyses varied not only with different strengths of sewage but also on identical samples of sewage. The curve representing the expected accuracy of the test may be plotted from the following data:

Chlorine Demand in p.p.m.	Deviation from the Average in p.p.m.	Per Cent Deviation
1	±0.04	4.0%
3	±0.06	2.0%
6	±0.1	1.6%
10	±0.2	2.0%
25	±0.6	2.4%
40	±1.0	2.5%

Maximum deviations in this range (1 to 40 p.p.m.) amounted to 15 per cent and in the lower ranges many deviations from the average were less than 1 per cent.

(*2*) *Effect of Contact Time on Chlorine Demand at Different Temperatures.*—In Fig. 1 are shown curves representing comparisons of the 2 minute and 10 minute chlorine demand with the 15 minute chlorine demand at 8 to 12 degrees C. and at 20 degrees C.

Discussing the curves separately, it appears that at 8 to 12 degrees C., the 2 minute chlorine demand drops rapidly above 2 p.p.m. to about 84 per cent of the 15 minute demand. At 20 degrees C. the drop is more rapid and the percentage of the 15 minute demand as evidenced in 2 minutes, is about 76 per cent of the total. In short, it may be said

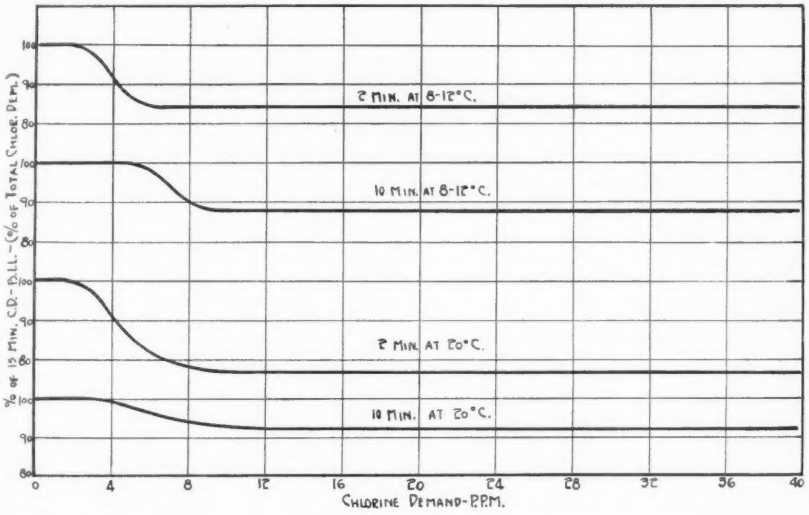

FIG. 1.—Relation of 2 minute chlorine demand and 10 minute chlorine demand to 15 minute chlorine demand, B. I. L. method, at different temperatures. 15 minute chlorine demand equals 100 per cent.

that the 2 minute demand represents the total demand only up to 2 p.p.m., regardless of temperature. Maximum variations from these general trend curves were as high as 110 per cent and as low as 63 per cent. In water at 1 and 2 degrees C. the 2 minute demand represented the total demand up to 5 p.p.m.

The 10 minute demand at the lower temperatures represents practically the total chlorine demand up to 5 p.p.m., and above 9 p.p.m. averages about 86 per cent of the total demand. At 20 degrees C. the 10 minute demand begins to drop (in percentage of the total 15 minute demand) at 3 p.p.m., and at 11 p.p.m. reaches a more or less constant level at 93 per cent of the total demand. Maximum results were 121 per cent and minimum results were 70 per cent of the total demand.

Though variable data were obtained at all concentrations of chlo-

rine demand, the variation above 40 p.p.m. appeared too great to determine a definite trend. Too few samples above this range may account for this inability to obtain a trend.

The 10 minute contact period does not appear sufficient above a chlorine demand of 5 p.p.m. at low temperatures, or 3 p.p.m. at 20 degrees C. A 15 minute contact time is indicated as representing the total chlorine demand below 40 p.p.m.; no change in chlorine demand

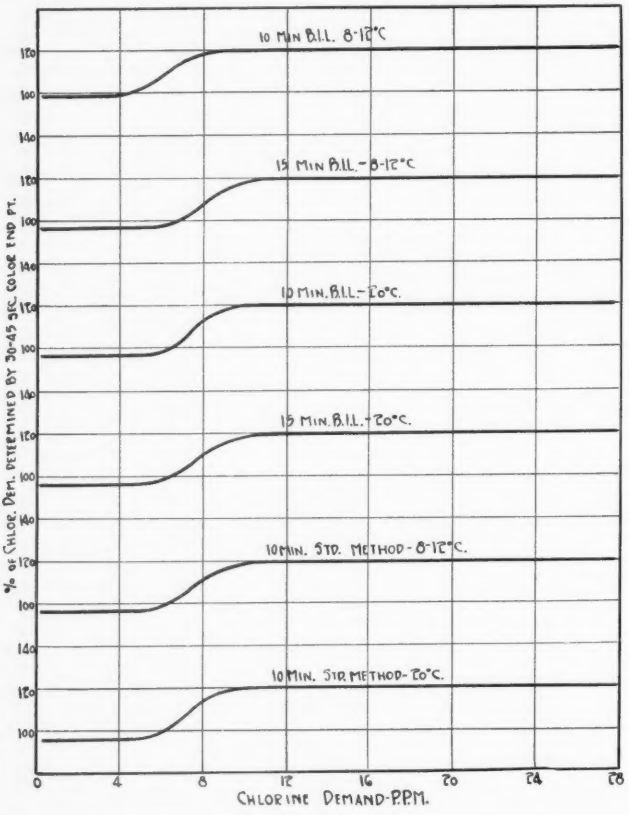

FIG. 2.—Relation of chlorine demand determined by 5 minute color endpoint to chlorine demand determined by 30–45 second color endpoint at different temperatures. Chlorine demand by 30–45 second color endpoint equals 100 per cent.

was noted after 15 minutes in that range. In the higher ranges of chlorine demand, especially above 2,000 p.p.m., 30 minutes or more was required to completely satisfy the chlorine demand of the waste.

It should be pointed out here that in Fig. 1 and all others, the curves should not be taken as an absolute definition of an exact relation that exists between one technique and another taken as a standard equal to 100 per cent. Rather, these curves and all others represent the trend of the data as determined on samples collected in Buffalo. It is

entirely probable that a somewhat different trend curve might be obtained on other sewages and in different locations.

(*3*) *Comparison of the Chlorine Demand Endpoint at One Minute or Less and After Five Minutes Standing.*—As stated in the description of the test, in the Bird Island Laboratory method the endpoint is read in one minute or less, as it was found that maximum color was developed in that time. Thereafter the color fades. McCrumb and Kenney [2] state that this time is usually less than 5 minutes.

Figure 2 presents the curves showing the relation between the chlorine demand as determined by the immediate maximum color endpoint and the 5 minute endpoint for different contact times, different methods, and different temperatures.

In the Bird Island Laboratory method for either 10 or 15 minutes contact time, and regardless of temperature, the 5 minute endpoint appears to give results, up to 4 to 6 p.p.m., that are 96 to 98 per cent of the demand, as determined by the immediate endpoint. Above that

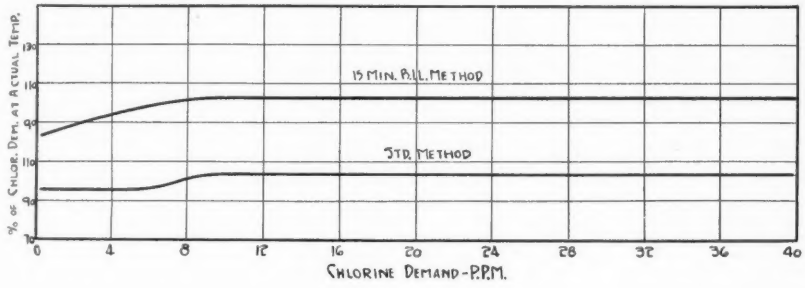

FIG. 3.—Relation of chlorine demand at 20° C. to chlorine demand at actual temperatures (8–12° C.).

range the 5 minute endpoint gives high results which reach an average high, at 8 to 10 p.p.m., of 120 per cent of those determined by the immediate endpoint. Maximum results obtained were 172 per cent and minimum results 76 per cent of those determined by the immediate color endpoint.

Similar results are obtained using the standard method. Generally speaking, these data substantiate McCrumb and Kenney's [2] statement that "readings . . . should be made at the point of maximum color formation rather than after a fixed time interval." Results obtained with the 5 minute endpoint may generally be expected to be high, except in low ranges.

(*4*) *Effect of Temperature on Chlorine Demand.*—In Figure 3 are shown the curves comparing the chlorine demand as determined on the same sample at different temperatures (8 to 12 degrees C. and 20 degrees C.). Only the data on the regular Bird Island Laboratory method (15 minute contact and immediate endpoint) and on the Standard Method (10 minute contact and 5 minute endpoint) are shown.

The lower temperature results are considered to be 100 per cent of the total demand and in the Bird Island Laboratory method, results at 20 degrees C. are less than those at 8 to 12 degrees C. up to 5 p.p.m. and about 104 per cent above 7 p.p.m. In the Standard Method similar results are obtained. However, it must be remembered that in the latter case it is assumed here that the test represents the total chlorine demand. Actually results are about 110 per cent of the total chlorine demand (see below). Maximum results of 134 per cent and minimum results of 65 per cent were obtained. In general it may be said that in the ranges of 10 to 20 degrees C., the effect of temperature will not cause an average variation in results of more than $\pm$ 4 per cent. At lower temperatures and ranges however, the results at 20 degrees are definitely less than those at the actual temperature.

(5) *Comparison of the Bird Island Laboratory Method and the Turbidity Compensated Tube Method for Chlorine Demand.*—In Figure 4 are shown the curves comparing the two methods at different temperatures. At 8 to 12 degrees C., considering the Bird Island Labora-

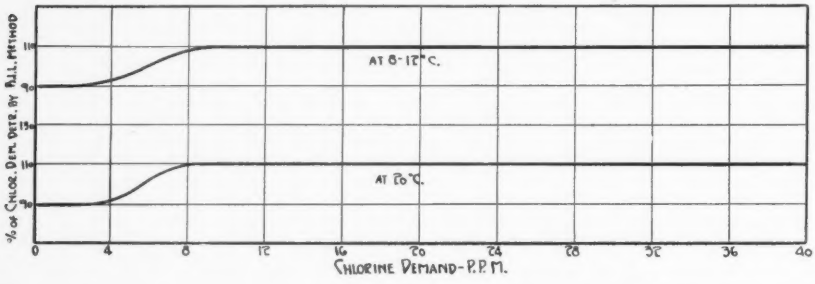

FIG. 4.—Relation of chlorine demand determined by standard method to chlorine demand determined by B. I. L. method at different temperatures.

tory method as 100 per cent, it appears that results by the tube method are only 90 per cent of the total chlorine demand up to 3 p.p.m. and are 110 per cent above 10 p.p.m. Maximum results of 142 per cent and minimum results of 83 per cent were obtained.

At 20 degrees C., using the Bird Island Laboratory method as a basis, results by the tube method are only 88 per cent of the total chlorine demand up to 3 p.p.m., and 110 per cent above 8 p.p.m. Maximum results of 159 per cent and minimum results of 77 per cent were obtained.

In Figure 5 shows the curve representing the trend in the relation between results by the Standard Method (10 ml. tubes, 10 minute contact time, 5 minute endpoint at 20 degrees C.), and those of the Bird Island Laboratory method (spot plate, 15 minute contact time, immediate color endpoint, actual temperature), with the latter taken as representing 100 per cent of the total actual demand. From this curve it appears that up to 2 p.p.m., the Standard Method represents only 80 per cent of the total demand. This percentage rises and reaches 110

per cent at 10 p.p.m. Maximum percentage obtained was 179 per cent; minimum percentage was 63 per cent. In general it appears that results by the Bird Island Laboratory method are less than those by the Standard Method above 7 p.p.m. This tends to explain the low chlorine demand results obtained in Buffalo.

It should be noted here that if a 15 minute contact time were allowed in the Standard Method, the results would be still higher because of the 5 minute endpoint (*i.e.* the increase in determined chlorine demand due to fading during the 5 minute endpoint is offset by the shorter contact period).

(*6*) *Determination of High Chlorine Demands on Industrial Wastes.*—In wastes having a chlorine demand of 2,000 to 6,500 p.p.m. it was found that contact times up to 30 to 40 minutes were required for complete satisfaction of the demand.

The accuracy of the test (B.I.L. method) is less than in the lower ranges and the deviation from the average of triplicate samples may be as much as $\pm$ 8.7 per cent.

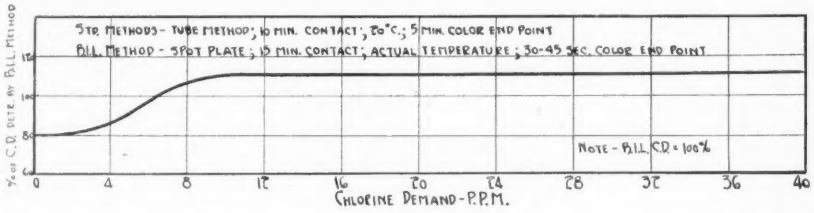

FIG. 5.—Relation of chlorine demand determined by standard method to chlorine demand determined by B. I. L. method.

In these highly colored wastes the Standard Method *can not* be used in any case. Dilution of the waste to a degree where the Standard Method can be used produces low results.

More ortho-tolidine must be added to the spot plate (Note—the ortho-tolidine should be added to the sample after spotting); 4 to 6 drops per ml. of sample are required.

The minimum readable color on these "strong" wastes is 0.2 to 0.3 p.p.m. of residual chlorine.

The effect of temperature was not determined.

CONCLUSIONS

From these studies of the chlorine demand test the following conclusions may be drawn.

(1) In normal sewages of 5 to 40 p.p.m. chlorine demand, a contact time of 15 minutes is required to allow for complete satisfaction of the demand. Below 3 to 5 p.p.m., 10 minute contact is sufficient.

(2) The temperature at which the test is performed is not particularly important, though results above 10 p.p.m. at 20 degrees C., are slightly higher than those at lower temperatures. In the case of ex-

tremely low temperatures and extremely low chlorine demand, the 20 degree results are lower. Other studies indicate that winter sewages in Buffalo have about 65 per cent of the chlorine demand of summer sewages but this should not be confused with the above statement.

(3) The endpoint of the test should be taken at maximum color development of the ortho-tolidine color (usually 30 to 45 seconds) rather than after a stipulated period of 5 minutes. High results are obtained with the latter technique except at low temperatures, and low chlorine demands where the reverse is true.

(4) The use of the spot plate method instead of turbidity compensated tubes (10 ml.) is indicated to be advantageous for the following reasons: (*a*) simpler technique, (*b*) applicable to strong wastes, (*c*) gives lower results, but results which produce the desired bacterial reductions (*i.e.* greater than 99 per cent), (*d*) residual chlorine of 0.1 p.p.m. is easily determined without standards, (*e*) residual chlorine up to 0.5 p.p.m. can be easily determined if properly standardized permanent standards are prepared.

(5) Though these data do not cover the point, from other studies it may be said that 0.1 p.p.m. of residual chlorine after 15 minutes contact is sufficient to produce the desired bacterial kill. As there is no further uptake of chlorine after 15 minutes in ordinary sewages, and the kill is sufficient with 0.1 p.p.m residual, the use of 0.5 p.p.m. residual chlorine as required in some instances [6] does not seem warranted where close chemical control of dosage is available. Since to produce 0.5 p.p.m. residual requires more than 0.4 p.p.m. additional chlorine, the difference in the chlorine added, using 0.1 p.p.m. residual, will amount to considerable saving in a large installation.

Acknowledgement

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CHEMICAL COAGULATION OF SEWAGE.* VIII. REMOVAL OF SUSPENDED SOLIDS AND B.O.D. BY STIRRING AND DIFFUSION OF GASES

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In order to evaluate the effect of chemicals on the removal of suspended solids and the reduction of B.O.D. it is necessary to know the effect of physical equipment employed with the introduction of the coagulants. In a previous paper [1] results were presented on the flocculation of sewage by various mechanical contrivances used in conjunction with coagulants. Air was compared with different types of mechanical flocculation. It was shown that mechanical mixing caused a definite increase in the removal of suspended material and a better floc formation was obtained. This phenomenon is not new, but was considered open to question, for sewage coagulation. The effect of air on clarification and stabilization has been observed by a number of investigations in this country and in England. Aeration of sewage has been used to some extent to obtain increased suspended solids removals. Whitehead and O'Shaughnessy [2] have called attention to the value of long detention times (8 hours or more) for increased suspended solids removal and greater stabilization. More recently, with the increased use of chemical coagulation and the necessity of having proper flocculators installed, the possibility of using flocculation without recourse to chemicals became more apparent and attempts have been made to utilize such processes.

In controlled experimentation with air and mechanical stirring devices it was found that the increased removals of suspended solids varied over a rather wide range, depending upon the length of period (30 to 60 minutes), but only small differences in removal were noted between mechanical (paddle) and direct aeration. This led to the belief that the removal of suspended solids was primarily caused by physical rather than biological factors, especially because the stirring was so slow and it was doubtful that aerobic conditions were maintained in the sewage flocculated by paddles during short periods. In the case of mixing with air the sewages were definitely aerobic, but the suspended solids removals were only slightly better than with mechanical stirring. Similar observations were made by Williams [3] who used nitrogen and air to determine their effects and employed stirring under both conditions.

Although the removal of suspended solids by mechanical means is well appreciated, the reduction in B.O.D. has not been evaluated to the same extent and the reduction per unit of time has not been established. It is of interest to determine whether flocculation without chemicals is

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as effective in lowering the B.O.D. values as the removal of suspended solids and turbidity indicate. Several questions of practical interest are involved. What is the effect of time and when does continued flocculation cease to be of practical value? Can biological flocculation be stimulated by the use of pure oxygen or ozone? What is the effect of a sterilizing agent such as hydrogen peroxide? What is the effect of practically anaerobic conditions caused by carbon dioxide as compared with nitrogen gas, considering that CO_2 makes the sewage acid? How far can flocculation with air or gases replace chemical coagulations? Only when answers to these and other questions are obtained can chemical coagulation of sewage be properly evaluated. It is the intent of this paper to present results dealing with different gases and varying flocculation times in an effort to determine their relative effects on B.O.D. reduction, and incidentally on clarification.

Methods and Materials

Mechanical stirring was accomplished in series of six 3-liter bottles as illustrated in Fig. 1. The gases used were carbon dioxide, nitrogen,

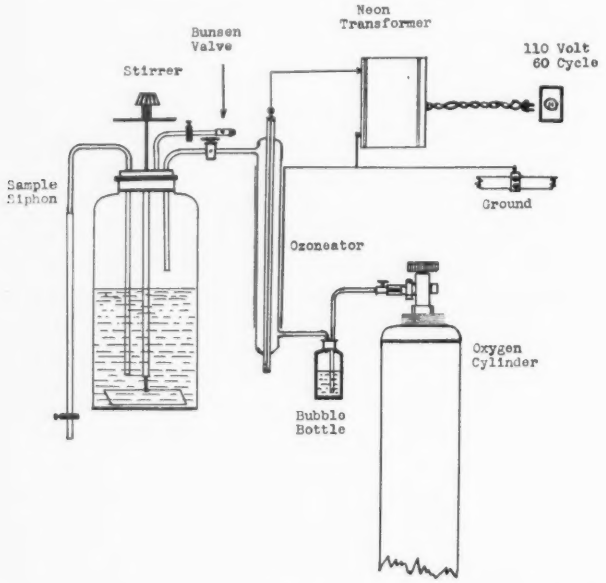

Fig. 1.

oxygen, ozone and air. Ozone was made by an attached ozonator, while the other gases were passed over the liquor directly from cylinders. The bottles were filled with sewage and all exit cocks closed. Half of the sewage was displaced (through sample siphons) by gas pressure, so that air was excluded. After closing the sampling siphon cocks and opening the outlets, a flow of gas was allowed to pass over

the sample continuously, escaping through bunsen valves which prevented back passage of air into the bottles. The bearing tubes of the stirring mechanism extended below the liquid level, thereby preventing entrance of air into the bottles. The paddles were then started and samples were drawn after varying intervals. The samples were allowed to settle in cylinders for 2 hours and the supernatant used for the determination of suspended solids, turbidity and B.O.D. All B.O.D. determinations were made with seeded water to take care of any bactericidal effect of the gases. The diffusion experiments were made in cylinders equipped with sintered glass discs. Hydrogen peroxide was added at the beginning of the experiments (40 p.p.m. as nascent O_2), adding additional quantities (20 p.p.m.) after ½ hr. and 2 hrs. stirring. All series were run with the same samples of sewage and repeated with different batches obtained from various sources.

Results

For the purpose of determining the effect of the different gases mentioned a strong, stale sewage was chosen, partly because a good deal of information was available on this type of sewage, partly because the percentage removal of suspended solids from a strong sewage is relatively large, and partly on account of the fact that this stale sewage contains a considerable amount of finely divided material. Complete runs were made on five different samples of this sewage mixed in the presence of the different gases, with stirring intervals of ½, 2 and 5 hours. After mixing, the samples were allowed to settle for two hours, while separate samples were submitted to quiescent settling for the same length of time without stirring or gas application. The average suspended solids content of the raw sewage was 378 p.p.m. and plain settling removed 56 per cent of the total suspended solids. The total suspended solids removal after stirring with air and different gases for ½ hour increased to 73 to 76 per cent, and after stirring for 5 hours the removal amounted to 81 to 84 per cent with the different gases. The increase over plain settling of 17 to 20 per cent of the total suspended solids removal, after ½ hour stirring in the presence of the different gases, is of sufficient interest to show the results on the turbidity and suspended solids removed and to calculate the additional removal of the finely divided material incapable of settling in two hours. The turbidity and suspended solids removal in p.p.m. and in percentages over plain settling are shown in Table I

The results show that the percentage removals of suspended solids were rather constant for the different types of treatment, but a general tendency is shown, with increased time, of somewhat greater removals in the order of air, oxygen, ozone, hydrogen peroxide, carbon dioxide and nitrogen. The method of determining removal of total suspended solids is not so effective as measurement of turbidity removal when the differences are small. Since comparisons are made of materials which do not settle under quiescent conditions and the par-

TABLE I.—*Turbidity and Suspended Solids Removal in Percentage Over Plain Settling (Average of Five Series)*

	Turbidity Removed after:						Suspended Solids Removed after:					
	½ Hour		2 Hours		5 Hours		½ Hour		2 Hours		5 Hours	
	p.p.m.	%	p.p.m.	%	p.p.m.	%	p.p.m.	%	p.p.m.	%	p.p.m.	%
Air	55	27	85	42	128	63	70	42	84	51	110	66
Oxygen	56	27	89	44	122	60	64	39	91	55	102	62
Ozone	47	23	75	37	119	58	68	41	90	54	105	63
H_2O_2	31	15	63	31	118	58	65	39	69	41	98	59
Nitrogen	44	22	67	33	110	54	71	43	76	46	94	57
Carbon dioxide	27	13	52	26	95	47	73	44	79	48	96	58
Plain settling			204						166			

ticular interest lies in the removal of the finely divided suspended substances, measurement of turbidity removal appears to be a better index. The results indicate that after ½ hour treatment air and oxygen are on a par, with ozone and nitrogen somewhat less effective and hydrogen peroxide and carbon dioxide removing the smallest additional percentage of finely divided material. After 5 hours treatment from 47 to 63 per cent of the turbidity remaining after 2 hours quiescent settling was removed by the treatment with different gases. It is of interest that carbon dioxide yielded relatively the poorest results. The addition of CO_2 caused the pH of the sewage to drop to 5.8, bringing it into the zone where a gradual decrease in turbidity removal takes place. The oxidizing agents ozone and hydrogen peroxide showed no advantage over air and oxygen, in spite of the fact that some bleaching and oxidation could be expected.

The rate of turbidity removal by stirring in the presence of gases is greatest during the first half hour. This is illustrated by the calculations shown in Table II, where the p.p.m. turbidity removal per

TABLE II.—*Rate of Turbidity Removal by Stirring in the Presence of Gases (P.P.M. Turbidity Removed per Hour)*

	Air	Oxygen	Ozone	N_2	H_2O_2	CO_2
During 1st ½ hour	110	112	94	88	62	54
During next 1½ hours	20	22	19	15	21	17
During last 3 hours	14	11	15	14	18	14

hour are given. During the next 4.5 hours the rate of turbidity removal changes only slightly and is nearly constant for all gases.

The corresponding removal of B.O.D. is shown in Table III. The average B.O.D. of the settled sewage samples was 313 p.p.m. As in the case of suspended solids and turbidity removal, the greatest reduction of B.O.D. occurred during the first half hour. It is of considerable interest to note that the B.O.D. removal caused by stirring was

TABLE III.—*B.O.D. Removal by Stirring in the Presence of Gases, Expressed in Percentage Over Plain Settling*

	After ½ Hour		After 2 Hours		After 5 Hours	
	p.p.m.	%	p.p.m.	%	p.p.m.	%
Air	50	16	80	26	138	44
Oxygen	63	20	78	25	140	45
Ozone	52	17	101	33	146	47
Hydrogen peroxide	100	26	111	29	138	36
Nitrogen	50	16	65	21	78	25
Carbon dioxide	52	17	52	17	78	25

Note: Average of 5 samples, except H_2O_2 average of 2 samples.

hardly influenced by the different gases during this time. The rate of reduction decreased thereafter for all mixtures, but the sewages to which oxygen was supplied in the form of air, oxygen or ozone maintained a higher rate of removal per hour than those supplied with nitrogen and carbon dioxide.

The turbidity removals during the first half hour of stirring in the presence of gases did not correspond to the even rate of B.O.D. reduction. During the next 4.5 hours the rate of B.O.D. reduction decreased greatly and became less with nitrogen and carbon dioxide. The rate of turbidity removal, calculated per hour, was materially less as compared with the first half hour, but was fairly constant for all gases.

TABLE IV.—*B.O.D. Remaining After Stirring and Aeration in the Presence of Air and Nitrogen*
Flocculation without Chemicals

Time Elapsed	Stirred						Aerated					
	Air			Nitrogen			Air			Nitrogen		
	B.O.D. Settled	Seitz	Turb. Remaining	B.O.D. Settled	Seitz	Turb. Remaining	B.O.D. Settled	Seitz	Turb. Remaining	B.O.D. Settled	Seitz	Turb. Remaining
	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
½ hour	199	99	156	196	102	184	215	96	190	209	94	228
2 hours	190	91	108	204	107	162	194	88	178	206	101	204
5 hours	162	74	88	188	105	162	165	48	120	199	100	184
Settled	210	102	312					40				

This is graphically illustrated in Fig. 2. These observations led to the belief that the greater B.O.D. reduction was due to the oxidation of the so called soluble oxidizable fraction of the sewage. In order to determine whether this assumption was correct, B.O.D. determinations were made on the settled sewage, its Seitz filtrate and on the settled sewage and Seitz filtrate after 5 hours stirring in the presence of different gases. The results of stirred and aerated sewage in the presence of air and nitrogen obtained after different periods are shown in Table V for illustration, while the B.O.D. of the finely divided ma the raw sewage was 386 p.p.m., settled sewage 312 p.p.m. and Seitz filterial and soluble substances is shown in Table VI. The B.O.D. of

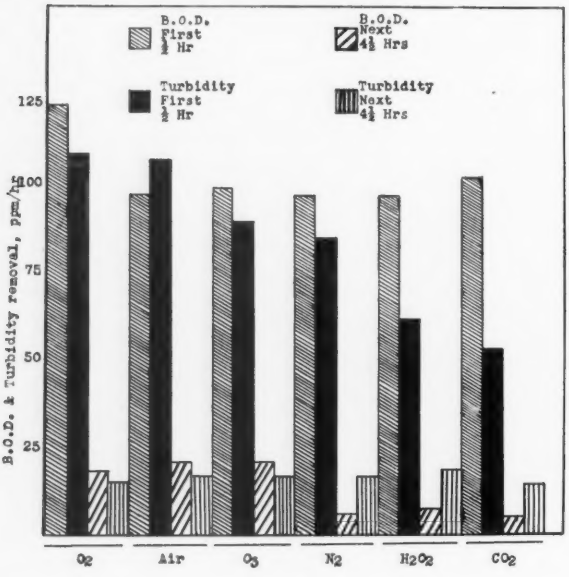

FIG. 2.

TABLE V.—*B.O.D. Remaining Due to Finely Divided and Soluble Substances After Stirring and Aeration in the Presence of Air and Nitrogen (Expressed in P.P.M.)*

Time	Stirred						Aerated					
	Air			Nitrogen			Air			Nitrogen		
	Fine	Sol.	Total	Fine	Sol.	Total	Fine	Sol.	Total	Fine	Sol.	Total
½ hour	100	99	199	94	102	196	119	96	215	115	94	209
2 hours	99	91	190	97	107	204	106	88	194	105	101	206
5 hours	88	74	162	83	105	188	117	48	165	99	100	199

TABLE VI.—*Effect of Diffusion of Gases on B.O.D. Removal Expressed in P.P.M. Remaining*

	Ozone	H_2O_2	O_2	Air	N_2	CO_2
½ hr.						
Turb.	207	218	190	198	220	205
B.O.D.	250	255	242	232	258	253
2 hrs.						
Turb.	180	190	178	185	192	188
B.O.D.	207	218	196	203	221	234
5 hrs.						
Turb.	140	148	133	137	158	155
B.O.D.	181	186	172	178	225	235

trate 102 p.p.m. The results and calculations show that about half of the B.O.D. is attributable to finely divided suspended material and the other half to soluble substances. The reduction in total B.O.D. appears therefore to be due to turbidity removal and oxidation.

Further experiments were conducted to determine the effect of diffusion of the gases as compared with stirring in the presence of gaseous atmospheres. Results of a series obtained with a strong sewage containing 420 p.p.m. suspended solids and a B.O.D. of 489 p.p.m. are given in Table VI as an illustration. The settled sewage had a turbidity of 240 p.p.m. and a B.O.D. of 330 p.p.m. In these experiments the gases were passed through the samples with the aid of diffusers. It is evident from the results that an appreciable reduction in B.O.D. took place over that removed by plain settling. The greatest removal took place during the first half hour. The rates of B.O.D. removal by bubbling gases through the liquid, expressed in percentages over the settled material, are graphically shown in Fig. 3. After the first half

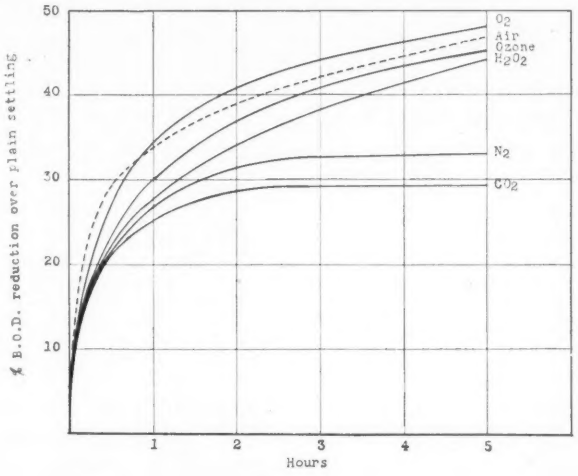

FIG. 3.

hour the B.O.D. removals of the settled sewage in the presence of nitrogen and carbon dioxide decreased rapidly and no further removal took place after 2 hours. The B.O.D. reduction of the samples subjected to oxygen-bearing gases was slower after the first half hour but continued for the entire period of 5 hours. Comparison of these results with those obtained by stirring in the presence of gases shows that the B.O.D. removal by gas diffusion was practically the same after 5 hours as when stirring was applied. The mixture subjected to N_2 and CO_2 were slightly poorer when stirred.

Of greatest interest are the B.O.D. removals obtained after ½ hour. A comparison of the results by stirring with those obtained by diffusion shows the following percentages B.O.D. Reduction:

	Diffusion	Stirring
Air	30	16
Oxygen	27	20
Ozone	24	17
Hydrogen peroxide	23	26
Nitrogen	22	16
Carbon dioxide	23	17

Evidently the bubbling of gases produced a more effective mixing than stirring in the presence of the same gases. Attention is called to the fact that these percentage removals are in addition to those which could be obtained by plain settling alone.

Discussion

Examination of the results presented show that when sewage was stirred in the presence of air or gases a greater removal of suspended solids and greater B.O.D. reduction resulted than with plain settling. Visual observation led to the belief that the suspended solids removal was caused by the agglomeration of the finely divided and pseudo-colloidal material because the stirred and settled samples were more free of readily visible non-settleable particles than the settled samples. This agglomeration or coagulation appears to be mainly physical in character, since removals of turbidity occurred in atmospheres of nitrogen, as well as in atmospheres of other gases, which would be inimical to aerobic bacterial flocculating activity. However, it is possible that clotting enzymes present in the sewage play a role. If sustained aerobic activities were important for clarification of sewage it could be expected that the eventual removal of suspended material would be greater. Examination of the results indicates that oxygen bearing gases were more effective in a shorter time, but eventually about the same percentage total suspended solids and turbidity removal took place under all conditions. In addition the carbon dioxide and hydrogen peroxide which can be considered deleterious to aerobic activity did not show greatly different results than the nitrogen, in spite of the fact that these gases may have some chemical effect on the agglomeration or at least would act as conditioning agents to air coagulation by changing the pH values of the liquid. At any rate the differences in turbidity removal were of such a low magnitude that the methods employed did not register them and they are therefore insignificant from a practical standpoint. Continued stirring in the presence of gases after the first half hour caused additional suspended solids removal but at a greatly reduced rate.

Reduction of B.O.D. caused by stirring in the presence of gases amounted to from 16 to 20 per cent during the first half hour, in addition to the removal caused by settling. Thereafter the reduction of B.O.D. in the presence of oxygen-bearing gases continued at a slower rate, but the rate of reduction in the presence of nitrogen and CO_2

was practically nil. The results of the tests when gases were bubbled through the liquid show a greater rate of B.O.D. reduction during the first half hour but the final result after 5 hours were substantially the same as with stirring. The fact that no appreciable continued B.O.D. removal took place with nitrogen and CO_2 and turbidity removal was only slight after the first half hour indicates that oxidation was taking place in the soluble fraction of the sewage. This was further emphasized by the fact that B.O.D. removal by bubbling oxygen-bearing gases was greater than by stirring in the presence of the same gases, and especially by the difference of B.O.D. reduction in the soluble part when stirred and aerated with nitrogen and air. A comparison of the B.O.D. remaining in the Seitz filtrates after stirring for different periods with direct diffusion of air and nitrogen (Fig. 4) illustrates this more clearly. No reduction in the B.O.D. of the soluble fraction

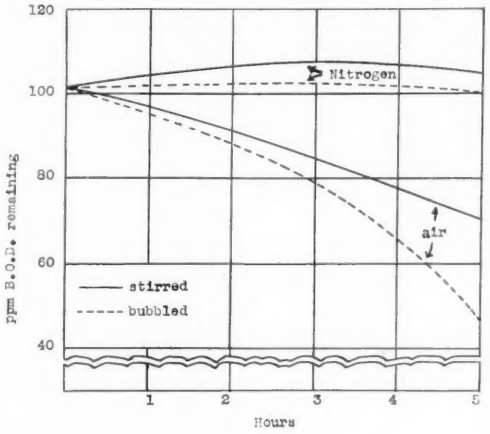

FIG. 4.

took place when stirring or bubbling with nitrogen was employed. Further discussion on the mechanism of B.O.D. reduction in regard to physical, chemical and biochemical factors will be presented in a future paper.

The greater B.O.D. reduction by oxidation of the soluble fraction by diffused air as compared with stirring in the presence of air appears to be counterbalanced by the increased reduction of the suspended B.O.D. produced by the latter method. The final total B.O.D. reduction for the diffused air amounted to 47 per cent, while the total B.O.D. reduction after ½ hour was 31 per cent for stirring, with air, and 36 for direct air, over the settled sewage. It is evident therefore that considerable B.O.D. reduction can be accomplished either by stirring in the presence of air or by blowing air through the sewage for a comparatively short time.

The results presented are primarily for the purpose of showing qualitatively the mechanism active in the processes and not for calcu-

lation of expected removals in full-scale operation. They indicate, however, that flocculation without chemicals can accomplish a considerable removal of B.O.D. as well as suspended solids. With large tanks poorer flocculation can be expected than in the laboratory, because aeration or stirring would not be so effective and fluctuations in sewage flow would tend to produce changes in time of flocculation as well as increased short circuiting. The oxidation effect on stirring would likely decrease when the depth of the liquid is great, with a tendency toward better results with direct aeration. Experiments on a plant scale employing a stirring mechanism revolving at different rates, with and without the addition of chemicals, have been made and are to be published soon.

The failure of pure oxygen to register additional oxidation over air is probably because absorption of oxygen from the air was sufficient to maintain aerobic condition. Excessive amounts of oxygen do not accelerate oxidation materially. The question might be raised whether much of the oxidation taking place is due to chemical oxidation. If chemical oxidation was playing an important role we could expect that ozone would produce more rapid results. This appears not to be the case. It is possible that the ozone was rapidly broken down and the nascent oxygen changed to the molecular form. This nascent oxygen would retard biological oxidation on account of its germicidal effect. However, since no appreciable increase in total oxidation could be found, the effect of any chemical oxidation by nascent oxygen was not greater than that caused by biological oxidation.

Further evidence is afforded by the action of hydrogen peroxide. This compound acts as a germicidal and active oxidation agent, and no increase, but actually a decrease in the total and rate of oxidation took place. If chemical oxidation was caused by the hydrogen peroxide it could only account for a fraction during the last 4½ hours, because practically half of the oxidation took place during the first half hour. If the oxidation during the first half hour was chemical, practically no oxidation should take place in the presence of inert nitrogen gas. However, the total and rate of oxidation during the first half hour in the presence of nitrogen was not materially less than with hydrogen peroxide. The fact that the total oxidation and rate of oxidation with hydrogen peroxide were less than with other oxygen bearing gases appears to indicate retardation by germicidal action. From all evidence obtained it can be concluded that very little chemical oxidation takes place, and if any, of the more easily oxidizable soluble substances.

Summary

Sewage was stirred in the presence of air, oxygen, ozone, nitrogen, carbon dioxide and hydrogen peroxide and also subjected to bubbles of the same gases without the aid of a stirring mechanism. Increased removals over plain settling of B.O.D., turbidity and suspended solids were observed. During short periods of one-half hour, all gases

showed approximately the same removals, with no reduction in soluble B.O.D. It appears that B.O.D. reduction was caused by the removal of finely divided and pseudo-colloidal material by physicist agglomeration. Continued treatment led to B.O.D. reductions in the soluble fraction when oxygen bearing gases were used. No further oxidation was observed with CO_2 and nitrogen, but removal of suspended solids was about the same as with other gases. Oxidation was greater and the rate higher with diffusion of air as compared with stirring, but turbidity removal was somewhat poorer. The reduction in B.O.D. after prolonged treatment (5 hours) was about the same for both methods. Oxygen, ozone, and hydrogen peroxide were for practical purposes no more effective than air in promoting oxidation. Under laboratory conditions, over 40 per cent suspended solids could be removed in 30 minutes, while turbidity removal amounted to about 25 per cent and B.O.D. reduction over 30 per cent, in addition to that obtained with plain settling, making total suspended solids and B.O.D. reductions of about 73 to 76 and 46 to 60 per cent, respectively, depending upon the method of stirring and mixing used. It is expected that flocculation without chemicals on a plant scale would not produce the same extensive removals of suspended solids and B.O.D. reduction in a short time.

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Plant Operation

SEWAGE TREATMENT PLANT AT NORTH ADAMS, MASSACHUSETTS *

By Frank L. Flood

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The city of North Adams is situated in northeastern Massachusetts, at the confluence of the north and south branches of the Hoosic River. The present population of the city is approximately 22,000. There has been little, if any, growth of the city for the past 35 years. The principal industries are related to the manufacture of textiles.

Below the confluence of the two branches of the Hoosic River the stream flows through the westerly part of North Adams, following a somewhat meandering course. It is crossed twice by the state highway and at four other places by secondary roads. In several localities the stream passes through residential areas. The drainage area at North Adams is 120 sq.mi. The estimated average minimum monthly flow is 45.4 c.f.s. and the minimum month 26.5 c.f.s.

Below North Adams the river flows through agricultural land until it reaches the central part of Williamstown 5 miles below the confluence of the north and south branches. At Williamstown the greater part of the village has been developed some distance from the stream. The sewage of this town is discharged to the river without treatment. Below Williamstown the river continues to flow through agricultural country most of the distance on its way to enter the Hudson River near Mechanicsville, New York. The stream below North Adams is not used for water supply, but is used to some extent for industrial purposes.

The city of North Adams is sewered on the separate system. Prior to the recent construction, a large outlet serving nearly three-quarters of the sewered area discharged to the river about 1,500 ft. below the confluence of the two branches. There were a number of smaller sewer outlets most of which discharged to the river below the main outlet. The industrial wastes were discharged in large part direct to the river in the city.

The discharge of untreated sewage and industrial wastes brought about a seriously objectionable condition of the water below the confluence of the two branches. Solids from the sewage and wastes settled upon the bed of the stream at numerous points of quiet water, and as a result of the decomposition of these solids, floating masses of offensive sludge rose to the surface from time to time. Furthermore,

* Presented before the Eighth Annual Meeting of the New England Sewage Works Association, Pittsfield, Mass., Oct. 2, 1936.

decomposition processes brought about offensive odors which were distinctly objectionable to the inhabitants in the vicinity of the stream.

The development of certain areas in the city required the extension of sewerage facilities. The Massachusetts Department of Public Health would not approve the construction of further sewers or sewer outlets to the river until the city made provision for treatment of the sewage.

Industrial Wastes.—A survey disclosed that the quantity of industrial wastes actually admitted to the sewers of the city is very small, probably not in excess of 50,000 g.d. The total quantity of industrial wastes was found to be about 10 m.g.d. or from 4 to 5 times the normal domestic sewage flow. Probably two-thirds of the industrial wastes consist of relatively clean waste waters or are wastes containing inorganic matters. It was concluded necessary to continue the exclusion of industrial wastes from the sewer, and no provision has been made for them in the intercepting sewers or at the sewage treatment plant.

To correct the unsatisfactory conditions caused by the discharge of untreated sewage to the river at various points, an intercepting sewer about two miles long was built from the end of the main sewer outlet westerly down the river valley to a fairly well isolated site above the Blackinton mills on the north bank of the river about three-quarters of a mile from the Williamstown line, this site having been suggested by the Massachusetts Department of Public Health. A sewage treatment plant was constructed, providing for sedimentation and chlorination of the sewage. Provision was made for the digestion of the sludge in separate tanks and drying of the digested sludge on glass-covered sludge-drying beds. The design of the treatment plant was based on a tributary population of 22,000 and an average sewage flow of 2.5 m.g.d. A general plan of the treatment plant is shown in Fig. 1.

A small area between the treatment plant and the Williamstown line known as the Blackinton District is served by a separate sewerage system from which the sewage is pumped to the treatment plant.

Sewage Treatment Plant

Rack.—A mechanically cleaned bar rack is provided at the entrance to the treatment plant. The rack channel is 3 ft. wide and the clear spacing between the bars is 1½ in. The rack cleaning mechanism was furnished by the Jeffrey Manufacturing Company. The rack is motor-actuated and the operation is controlled by a time-switch.

The rakings are discharged into a hopper and automatically flushed into a Jeffrey shredder which operates in synchronism with the rake. The purpose of the rack is to intercept the large and coarse solids in the sewage which would interfere with the effective operation of subsequent sludge handling equipment, particularly sludge pumps and pipe lines. The shredder is provided to chew, mash, or cut up these solids so that they may be returned to the sewage and treated with the other sewage solids. Otherwise, special handling, treatment and dis-

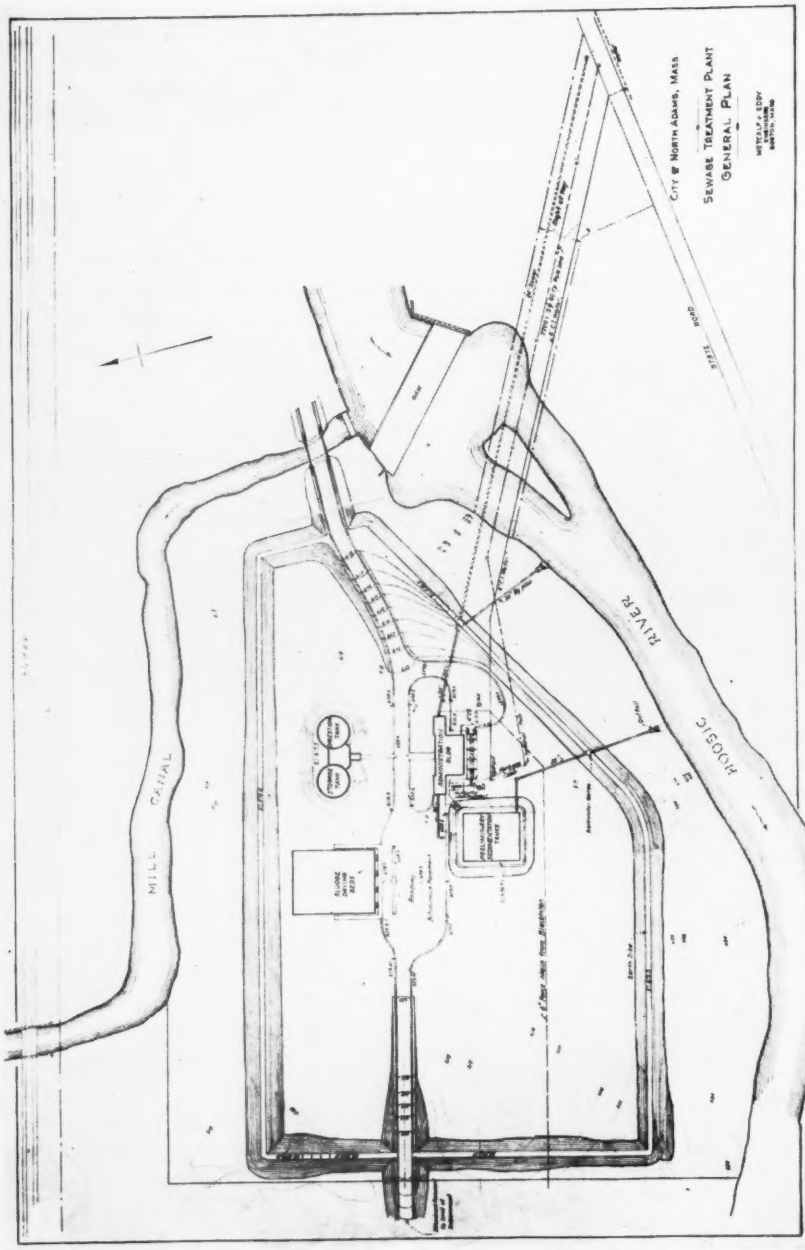
CITY OF NORTH ADAMS, MASS.
SEWAGE TREATMENT PLANT
GENERAL PLAN
MILL CANAL
HOOSIC RIVER
STATE ROAD

FIG. 1

posal of the rakings would be required. The rack, raking equipment and shredder are housed in a room at the administration building.

Venturi Meter.—From the rack channel the sewage passes through a Venturi meter. A 24 in. by 10 in. Venturi tube is provided and a Type M register having rate indicator, rate recorder and quantity totalizing dial as manufactured by Builders Iron Foundry, has been installed.

Sedimentation Tanks.—Three sedimentation tanks are provided, each tank 60 ft. long, 16 ft. wide and with an average effective depth of 10 ft. The theoretical detention period, at a rate of flow of 2.5 m.g.d., is 2 hours. The tanks are equipped with sludge removal mechanisms of the scraper conveyor type, manufactured by the Jeffrey Company.

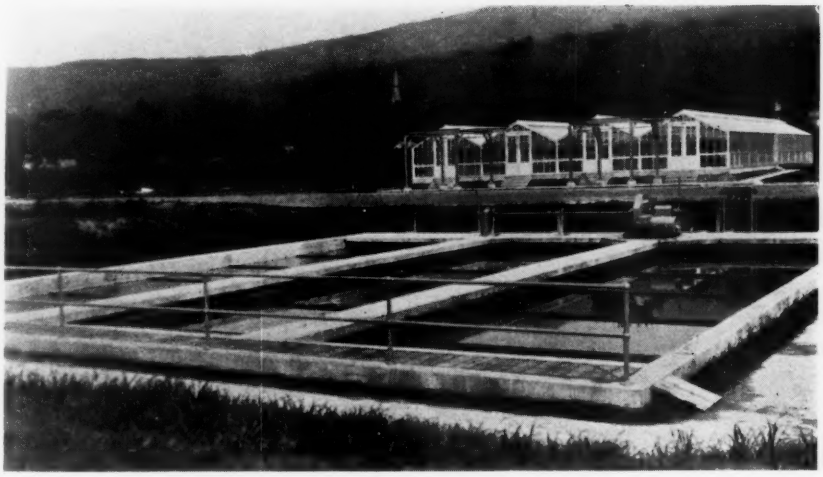

FIG. 2.—Sedimentation tanks in foreground, glass covered sludge drying beds in background.

The return flight of the mechanisms skims the surface of the tank. The scum is removed by means of a hand skimmer at the effluent ends of the tanks and dumped into a chamber which is connected with the sludge withdrawal piping in such a manner that the skimmings may be disposed of with the sludge.

The effluent from the sedimentation tanks discharges to the river.

Raw sludge is drawn from the hopper at the influent end of the sedimentation tanks by means of a Rex duplex plunger sludge pump manufactured by the Chain Belt Company, and pumped to the sludge digestion tank. The sludge pump is located in a pump room at the administration building.

Chlorination Plant.—Provision is made for chlorination of the sewage ahead of the sedimentation tanks. Two Type MSVM manually controlled chlorinators, vacuum solution feed, manufactured by Wallace & Tiernan, each having a maximum capacity of 300 lb. of chlorine per

24 hours, have been provided. The chlorinators have been installed in a room within the administration building.

Provision has been made for the use of chlorine in ton containers and carload lots. Storage space for 18 containers is provided in the rear of the administration building, upon rails under a structural steel frame supporting a monorail trolley hoist. Chlorine in ton containers, brought to the plant on trucks, may be unloaded from the trucks by means of the hoist and placed on the rails. Chlorine may be taken to the feed machines directly from the ton containers on the rails. Chlorine from cylinders may also be used and so far such has been the case.

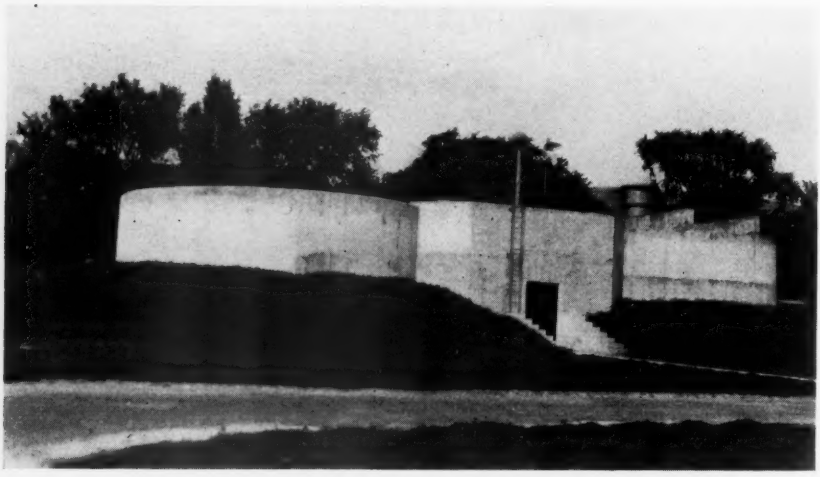

FIG. 3.—Sludge digestion tank on right, sludge storage tank on left.

The combined capacity of the two chlorinators would supply chlorine at a rate of 10 p.p.m. for a rate of sewage flow of 5 m.g.d. Chlorination is provided primarily for use in the warm dry months of the year as a means of controlling odors at the sedimentation tanks and from the plant effluent.

Sludge Digestion and Storage Tanks.—The sludge digestion tank is 35 ft. in diameter and 21 ft. 6 in. side wall depth. The bottom is an inverted cone with slope of 4 in. to 1 ft. giving a depth of cone of 5 ft. 10 in. The overall depth of tank is 27 ft. 4 in. The tank is covered with a fixed concrete roof. It is equipped with nine 2½ in. wrought iron heating coils supported 12 in. from the wall. The digestion tank capacity is 22,500 cu.ft., or slightly more than 1 cu.ft. per capita, on the basis of the population of design. The sludge storage tank is an open tank with an overall side wall depth of 22 ft. 3 in. Otherwise it has the same dimensions as the digestion tank. The storage tank provides for the storage of the digested sludge during the colder months

of the year when the rate of drying sludge on the glass-covered beds is considerably retarded.

A gallery formed between the digestion and storage tanks encloses piping connections, gas controls, sampling pipes and a digested sludge pump. This pump is a duplicate of that described for pumping raw sludge and may be used for pumping sludge from the digestion tank to the storage tank or from either tank to the sludge drying beds.

The gas control equipment includes flame traps, water seal and condensate trap, pressure control and relief valves and meters on used gas and waste gas lines.

Sludge Drying Beds.—The sludge drying beds comprise eight units, each unit about 45 ft. long by 17 ft. 3 in. wide. The beds are enclosed by a single glassover of the ridge and furrow type. A monorail sludge handling system is provided, with two chain hoist carriers and two ½-yd. buckets. The monorails extend longitudinally over the center line of each bed and permit direct unloading of the buckets into trucks at a loading platform in front of the glassover.

The effective drying area is 5,900 sq.ft., equivalent to about .27 sq.ft. per capita.

Administration Building.—This building houses the rack and chlorination equipment, sludge and drainage pumps, Venturi meter and register, laboratory, central heating unit and locker room.

The drainage pump, in addition to serving as a means of emptying the sedimentation tanks, also provides for the discharge to the river of surface drainage from within the area enclosed by a dike around the sewage treatment plant.

A laboratory is provided, completely equipped, for doing the normal analytical work desirable in following the operation of a sewage treatment plant of this type and size.

The steam heating boiler includes copper tubular water heating surface for heating the hot water circulated in the digestion tank. The gas collected over the top of the digestion tank is utilized for heating purposes and if supplementary heat is required, an oil burner is available. Excess gas above that used at the heating plant, is disposed of in a waste gas burner.

A hot water circulating pump, having a capacity of about 45 g.p.m., is provided for circulating the water in the sludge digestion tank.

The construction cost of the plant excluding engineering was about $145,000 or $58,000 per million gallons per day of rated capacity. The work was carried out as a P.W.A. project.

Plans for the sewage treatment plant were prepared and construction started during the administration of the Hon. Archie J. Pratt, Mayor, and under the direction of Mr. John Miller, Commissioner of Public Works. Subsequently construction was completed and the plant operated under the administration of Hon. William Johnson, Mayor, and under the direction of Mr. Eolus R. Doble, Commissioner of Public Works. Metcalf & Eddy prepared the plans and have supervised construction and operation. During the first year of operation

Mr. Frank A. Nicoli, Assistant Engineer, was resident operator for Metcalf & Eddy, and Mr. Paul Fleming was assistant operator. At the end of the year complete control of operation was taken over by the city and Mr. Fleming became chief operator.

Plant Operation

The plant was placed in operation during September of 1935. During the dry weather periods including the months of September, October, and November, 1935 and June, July, and August, 1936, the average sewage flow was 1.74 m.g.d. as compared with 2.5 m.g.d., basis of design. The daily flow during the months of wet weather flow has averaged 2.74 m.g.d or somewhat more than the basis of design.

The efficiency of sewage treatment is measured at the plant only by the determination of settling solids. The average removal has been 93 per cent.

As a further degree of treatment, prechlorination of the sewage was started on June 16, 1936, with an average dose of 7 parts per million and was continued until September 1, 1936, when the plant was shut down for the installation of scum spraying equipment in the digestion tank.

The mechanical equipment for raking the rack has on the whole operated in a satisfactory manner. For a time, the equipment was overloaded by large quantities of sewage fungi flushed out of the sewers.

The shredder has been a source of considerable operating difficulty. The unit as first installed was not satisfactory as it clogged, overloaded easily and required too much attention by the plant operators. The Jeffrey Co. installed a new type of rotor June 23, but this did not prove satisfactory because of the large amount of attention and care necessary to keep it working properly. Further changes in the equipment were made on September 23, 1936.

After these changes the shredder has operated in a satisfactory manner. Generally the rakings are allowed to accumulate in the shredder hopper during the night and are manually fed to the grinder about once each hour during the day shift. When the load of rakings is light, a longer period of time between grindings is allowed. The shredder now clears itself readily and for a period of three months it has not been necessary to clean out, by hand, material which formerly accumulated in the bar cage below the cutting hammers.

The normal current consumption during the operation of the shredder is 20 to 25 amperes. Where the rakings are first fed to the shredder a momentary load of 28 amperes is normally experienced.

The operation of the sedimentation tanks has not presented any unusual difficulties except for the flotation of sludge solids at times in relatively large quantities during the early months of operation. Apparently this difficulty has been overcome by making sure to pump out

the sludge hoppers entirely clear of sludge each time sludge is pumped, which normally is done every other day.

Very little difficulty is now experienced in pumping sludge solids from the settling tanks to the digestion tanks. At times the sludge pump will be operated three hours a day for a week without clogging. The pump plunger packing has not required changing for five months. For several months, after the flood of March, 1936, considerable difficulty was experienced in the operation of the sludge pumps apparently because of the large quantity of sand and gravel which entered the sewerage system at that time. For much of this period it was necessary to station an operator at the sludge pump during its operation.

The digestion tank was heated to 85° F. on starting up but no seeding material was added. Gas production started early in November and had reached 2,000 c.f.d. by November 5, but then decreased to about 1,100 c.f.d. toward the last of the month. Gas was observed escaping from the overflow system. There was no evidence of any excessive accumulation of scum until the overflow pipe began to clog late in November.

Investigation on December 12, disclosed that 12 ft. or more of scum had formed in the tank. At the top and for a depth of several feet this scum was very dense, analyses indicating 23 per cent solids. The temperature of this scum ranged from 36° F. at the top to 52° at 2 ft. and 70° at 4.5 ft. depth.

An attempt was made to break up the scum by hosing and although this was partially successful, gas production did not increase. The pH of the sludge was very low, 6.3 in the sludge and 5.6 in the liquid zone between the sludge and scum. The sludge and scum was removed from the digestion tank to the storage tank, thoroughly liming and hosing it during the transfer, and then about half of it was returned to the digestion tank. The pH was raised to between 6.5 and 7.0 by this means.

Lime was then mixed with the raw sludge and added to the digestion tank until the pH increased to 7.4 but the production of gas was not encouraging. Following the flood of March, 1936, and during the period of Spring runoff, the sewage flow was discharged directly to the river. No sludge solids were added to the tank during the period from March 12 to May 3, except for a small quantity added on April 28. During this period of resting, the pH in the digestion tank was at all times above 7.0, the tank was maintained at a temperature of about 85° F. and any tendency for the formation of a dense scum was treated by hosing. No lime was added after March 20. The gas production during this period reached a maximum of 2,480 c.f.d. on March 16, and then dropped of rapidly.

In spite of the favorable pH and temperature conditions in the tank during this period, a scum blanket formed reaching a depth of about 7.5 ft. by the end of April. This scum layer was removed from the digestion tank and discharged to the storage tank through the overflow piping system. Starting May 3, sewage was treated at the rate of

1 m.g.d. during the day shift and the sludge solids deposited were discharged to the digestion tank.

Gas production started at once and by May 13, had reached a rate of 6,500 c.f.p.d. Treatment of part of the flow was continued until May 28, after which all of the sewage flow received treatment. Gas production immediately rose to 12,000 c.f.p.d. during June and continued at approximately this rate during the following months.

However, despite the favorable pH, temperature, and gasification condition in the digestion tank, scum started to form again and soon clogged the overflow piping connection. It was then decided to install a deeper overflow connection and scum spray piping in the digestion tank. This construction necessitated bypassing the plant starting September 1.

The plant was placed back in operation on November 2, 1936, treating about 1 m.g.d. until December 1, when treatment of all the sewage was undertaken. The surface of the digestion tank has been sprayed with warm supernatant liquor on the average of one hour each day. There have been no evidences of scum formation, the overflow liquor pipe has been relatively clear and the digestion tank has operated satisfactorily throughout the winter of 1936–1937.

The digested sludge drawn to the drying beds has drained and dried in a satisfactory manner. The dried sludge has been removed from the beds by farmers. At all times the demand for the sludge has exceeded the supply. The plant operators rake over the beds after the sludge has been removed. Some resanding will be required each year to maintain proper depth of material.

The cost of operation for the fiscal year September 15, 1935, to September 15, 1936, inclusive, was for salaries $3,300 and for expenses, $2,450, including power, fuel oil, lime and miscellaneous, making the total operation cost $5,750. The total sewage flow treated was 555 million gallons and the cost per million gallons was $10.37. The cost per capita was $0.26.

POLLUTION OF THE MOKELUMNE RIVER BY WINERY WASTES *

By Paul A. Shaw

Division of Fish and Game, State of California

Introduction.—The wine industry in the Lodi area, San Joaquin County, California, has developed rapidly during the past few years. With this development there has been an increased volume of waste disposal to the Mokelumne River, resulting in a pollution problem of major importance.

An initial survey of winery operations, character of waste products and methods of disposal, was conducted by the State Bureau of Sanitary Engineering during the 1933 season. These data have been summarized and published by DeMartini (1). The same bureau, in cooperation with the San Joaquin Local Health District, carried on a study of river conditions in 1935 and the Division of Fish and Game combined with these agencies for further investigations during the summer and autumn of 1936. Population equivalents established by DeMartini and other data from the several surveys have been utilized in preparing this paper.

Winery Wastes.—Wineries in the Lodi area are principally sweet wine and brandy producers and therefore operate equipment for the distillation of wine. The still slop from the distillation process is the major factor contributing to pollution of the Mokelumne River, thus creating a more acute problem than exists in areas suitable for dry wine, which do not require brandy for fortification.

Waste products from sweet wine manufacture include pomace, lees, wash water and still slops. The pomace is a garbage-like material composed of seeds, skins, particles of stems and heavy sediment separated from the new wine after fermentation of the crushed grapes. This pomace, totalling about 600 pounds per ton of grapes, is ordinarily disposed of on land and is not a factor in stream pollution.

The new wine, approximating 150 to 180 gallons per ton of grapes, is subsequently transferred from tank to tank and a thick sediment or sludge known as "lees" is separated. The method of handling lees varies to a considerable extent but in most instances this material is finally discharged to the sewer in combination with other liquid wastes. The principal source of danger from lees is their discharge in batch lots producing a slug of concentrated waste, a condition that has been observed several times in river studies. The volume of lees is 5 to 7 gallons per ton with a population equivalent approximating 35 persons.

Wash water from floors, tanks and filters produces a medium strength waste of 50 to 100 gallons per ton having a population equivalent of about 5 persons.

* Presented before the Ninth Annual Conference of the California Sewage Works Association, Stockton, April 23, 1937.

The still slop consists of all wine utilized as still material minus the alcohol content. The volume amounts to 0.9 gallons plus approximately 2 gallons of condensing water for each gallon of still material. The population equivalent per ton of grapes utilized as still material totals 225 persons. Approximately 40 per cent of the total tonnage is required to produce sufficient brandy for sweet wine fortification, but the Lodi area manufactures considerable brandy in excess of that necessary for sweet wines.

Plant operations are subject to wide variation, resulting in a marked fluctuation of waste, both in volume and strength. For this reason it is difficult to determine average or the most critical conditions existing in the river. Grab samples of waste from five wineries, tested by the Bureau of Sanitary Engineering, gave the following average values:

Oxygen consumed	6,800 p.p.m.
5-day B.O.D.	3,500 p.p.m.
Total solids	8,000 p.p.m.
pH	4.0

The value for oxygen consumed represents the true oxygen demand more nearly than the biochemical oxygen demand since winery wastes seem to inhibit normal biochemical activity in the B.O.D. dilutions. In river samples this effect has not been observed and Ingram, of the San Joaquin Local Health District, found that oxygen consumed and biochemical oxygen demands were practically identical on such samples.

In general, the mixed wastes are carbonaceous in character, and form an excellent medium, in river water, for the growth of various types of fungus. The best approximation of total population equivalent now available is 40 per ton of grapes plus 225 per ton of grapes utilized as still material.

Production Data and Pollution Load.—For the past two years, five wineries have discharged waste containing still slops to the Mokelumne River. These wineries handled 110,571 tons of grapes during the 90-day season of 1935 and 46,264 tons in the 60-day season of 1936. While the tonnage in the latter season was only 42 per cent of that in 1935, the records indicate 52 per cent with respect to still material. Due to a shorter season, the pollution load was reduced to a lesser extent and is calculated at 73 per cent of the 1935 load for the period of operation.

The average population equivalent for 1935 is calculated to be 224,000 with a maximum of 384,000 at the peak of operations, while in the following season the average population contributory to the river was calculated to be 163,000. An estimate of peak load for the 1936 season does not appear warranted since operations were more or less intermittent and it is questionable whether the river received capacity still wastes from all five plants at any time.

The flow of wastes to the river was estimated to average 450,000 g.p.d. in 1935 and 340,000 g.p.d. in 1936 with a maximum flow approaching 800,000 g.p.d. in 1935.

The pollution load contributed by the above wineries does not represent all of the potential load that could be discharged to the river, as there were three additional wineries in 1935 and six in the following year that were suitably located to use the Mokelumne River for disposal if permitted. The records on tonnage, still material and still capacities, for this group, indicate that the pollution load would have been increased 24 to 37 per cent in 1935 and 62 to 72 per cent in 1936, if this additional burden had been sewered to the river.

Available Dilution.—Water flow in the Mokelumne River is controlled at the Pardee Dam from which Oakland and other East Bay cities obtain their water supply. A smaller dam located at Woodbridge, a short distance below Lodi, serves to divert water for irrigation purposes. Four of the contributing wineries are situated in the area 3 to 6 miles above Woodbridge and the fifth a half mile below this point.

During the height of the season in November, 1935, the average flow was 560 sec. ft., with no diversion to the irrigation canal, providing a dilution of 2.5 sec. ft. per thousand for the average load of 224,000 population and a dilution of only 1.46 sec. ft. for the maximum load of 384,000. The flow in October was even less, averaging 515 sec. ft. above the dam and 432 sec. ft. below. In 1936, the operating peak was in October, the average river flow being 525 sec. ft. above the dam and 400 sec. ft. below, providing an average dilution of 3.2 sec. ft. per thousand for the load of 163,000, 96 per cent of which was discharged above the dam. Based on the formula given in the last edition of Standard Methods of Water Analysis, the above dilutions would result in 5-day oxygen demands in the river as follows:

Average 1935	12	p.p.m.
Maximum 1935	20.5	p.p.m.
Average 1936	9.3	p.p.m.

Physical Data.—Since river characteristics such as velocity, surface area, depth and elapsed time of flow have a marked bearing on the final effect resulting from organic pollution, a brief description of these factors appears desirable. For this purpose the Mokelumne River may be divided into four sections.

Section I extends from the first source of pollution to the Woodbridge Dam, a stream distance of 5.9 miles. While there are considerable areas of overflowed land in the lower half of this section, float tests indicate that the main flow of water follows the channel, the capacity of which is governed largely by elevation of the gates at the dam and is affected only slightly by changes in volume of flow.

Section II from the Woodbridge Dam to the Galt Bridge, a distance of 14.8 miles, is a meandering stream with well defined banks and fairly constant cross section. There are no large diversions of water or additional dilution from tributaries in this section.

Section III, covering a stream distance of 7.2 miles, from the Galt Bridge to New Hope Landing, is affected by tidal action, the upper limit being somewhat above the Galt Bridge. The direction of flow

reverses with the tide, moving the body of water up and down stream without additional dilution. The channel is wider and deeper.

Section IV, downstream from New Hope Landing, is still wider and much deeper, there being several side sloughs and channels before reaching Terminous, a distance of 10 miles. In the first 5.4 miles of this section on which capacity data were obtained, tidal action moves the body of water a greater distance than one day's flow, but without effecting any significant dilution with fresh water from the lower river.

Data on the four sections for conditions in October, 1936, calculated from float tests and from records of the U. S. Geological Survey and U. S. Coast and Geodetic Survey are given below.

	Section				Total
	I	II	III	IV	
Length—miles	5.9	14.8	7.2	5.4	33.3
Average depth—feet	8.	5.6	9.6	17.7	—
Surface area—acres	82.	180.	94.	136.	492.
Average downstream velocity—ft./sec.	.6	.75	.4	.11	—
Elapsed time of flow—hours	15.	29.	27.	72.	143.

The physical data indicate that critical conditions of oxygen depletion are more likely to occur above the Woodbridge Dam and in the tidal area below the Galt Bridge than would be anticipated in Section II. This fact is based principally on greater depth, resulting in proportionately higher demands per acre of available reaeration surface and less aeration with decreased velocity.

Chemical Data.—Determinations of dissolved oxygen, oxygen consumed, pH, and other sanitary and chemical analyses were conducted on samples from a series of river stations in 1935 and 1936. The three analyses first mentioned are the only ones reported here since significant changes were not observed in other components. As previously noted, 5-day biochemical oxygen demands on river samples were similar to oxygen consumed values so that only the latter are reported.

In 1935, the analyses were on samples collected during the period of winery operations at stations down to the Galt Bridge. In 1936, one survey was conducted on August 18, prior to the winery season, and a second on October 28, the testing stations extending from above the first source of pollution to New Hope Landing, a distance of 28 miles. On October 22, a survey, via boat, was made from the Galt Bridge to Terminous, and supplementary analyses were made at a number of stations during September and October. Table I covers the minimum oxygen and pH values and the maximum oxygen consumed values observed at the different stations. Table II indicates all determinations for the survey by boat on October 22.

From Table I, it will be noted that the minimum dissolved oxygen in August varied between 87 and 96 per cent saturation and that dur-

TABLE I.—*Mokelumne River Survey, 1935–1936*

Station	Stream Distance Miles	Minimum D.O. % Sat.			Maximum O.C.			Minimum pH		
		Aug. 1936	Sep. Oct. 1936	Oct. Nov. 1935	Aug. 1936	Sep. Oct. 1936	Oct. Nov. 1935	Aug. 1936	Sep. Oct. 1936	Oct. Nov. 1935
Above pollution	.0	96	92	95	1.5	3.8	3.1	7.1	6.8	6.5
C.C.T.C. Bridge	.4	—	—	95	—	—	16.4	—	—	6.4
Cherokee Bridge	1.7	91	84	89	1.6	8.8	13.7	7.1	6.6	6.0
Buck Beckman Line	3.7	96	72	85	1.8	7.9	14.5	7.2	6.6	6.5
Woodbridge Dam	5.9	87	60	64	1.9	10.1	13.7	6.9	6.6	6.5
Below Woodbridge Dam	6.0	95	88	78	2.1	—	13.0	7.1	—	6.5
2.4 mi. bel. W.D.	8.4	—	80	—	—	10.9	—	—	6.8	—
Acampo Road	9.1	—	79	—	—	10.6	—	—	6.6	—
Davis Road	12.0	96	77	70	2.3	14.5	14.2	7.1	6.5	6.5
Galt Bridge	20.7	90	76	64	2.6	6.6	14.4	7.0	6.7	6.0
Benson Ferry	23	87	61	—	2.3	9.0	—	7.0	6.7	—
New Hope Landing	27.9	89	46	—	2.3	5.5	—	7.0	6.7	—

TABLE II.—*Mokelumne River Survey, 1936*

Galt Bridge to Terminous Via Boat

October 22, 1936

Station	Time	Temp.	D.O. % Sat.	O.C.	pH
1 mile above Galt Bridge	11:16 a.m.	16.5	80	—	6.9
½ mile above Galt Bridge	11:10 a.m.	16.5	80	4.4	6.9
Galt Bridge	11:03 a.m.	16.5	81	—	6.9
5.0 miles above New Hope Landg.	10:58 a.m.	17	81	4.1	6.9
4.5 miles above New Hope Landg.	10:50 a.m.	17	81	—	6.9
4.0 miles above New Hope Landg.	10:43 a.m.	17	78	3.7	6.8
3.5 miles above N.H.L. (Benson Ferry)	10:38 a.m.	17	61	—	6.7
3.0 miles above New Hope Landg.	10:32 a.m.	17	61	5.5	6.7
2.5 miles above New Hope Landg.	10:27 a.m.	17	61	—	6.8
2.0 miles above New Hope Landg.	10:21 a.m.	17	60	6.1	6.7
1.5 miles above New Hope Landg.	10:15 a.m.	17	61	—	6.8
1.0 mile above New Hope Landg.	10:10 a.m.	17	64	4.7	6.7
0.5 mile above New Hope Landg.	10:04 a.m.	16.5	61	—	6.8
New Hope Landing	10:00 a.m.	16.5	62	4.4	6.8
New Hope Landing	1:10 p.m.	17.5	60	4.9	6.7
¾ mile below New Hope Landg.	1:17 p.m.	17.5	52	—	6.7
1½ miles below New Hope Landg.	1:23 p.m.	17.5	52	4.0	6.7
2¼ miles below New Hope Landg.	1:28 p.m.	17.5	60	—	6.8
3 miles below New Hope Landg.	1:36 p.m.	19	62	2.8	6.7
4 miles below New Hope Landg.	1:40 p.m.	19	56	—	6.7
6 miles below New Hope Landg.	1:48 p.m.	19	57	2.7	6.7
8 miles below New Hope Landg.	1:55 p.m.	19	75	2.8	7.1
9 miles below New Hope Landg.	2:05 p.m.	19.5	84	3.2	7.3

ing the winery season the minimum noted above the first source of pollution was 92 per cent. During the period of waste discharge, oxygen values fell rapidly from the first source of pollution to the Woodbridge Dam where a minimum of 60 per cent was observed. The dam serves as a valuable source of reaeration and the minimum noted immediately below this point was 88 per cent. Comparative tests indicated that the dam furnished a 60 per cent recovery of any existing oxygen deficiency. Below this point oxygen values again decreased with a minimum observed value of 46 per cent at New Hope Landing.

Maximum observed values for oxygen consumed rose from 2.6 before winery operations to 14.5 during the '36 season and to 16.4 for the '35 season. Minimum pH values dropped from 6.8 before the '36 season to a low of 6.5 in 1936 and 6.0 in 1935.

From Table II covering the tidal area survey by boat, it will be noted that oxygen values ranged from 52 to 64 per cent for a distance of 9½ miles, the lowest values being in the area below New Hope Landing. Since a value of 46 per cent had been previously noted at New Hope Landing, it is doubtful whether the above values represented the most critical conditions of the season below that point. It will also be noted from Table II that oxygen recovery was evident 8 miles below New Hope Landing and 30 to 36 miles below the major sources of pollution, the elapsed time of flow being 7 to 8 days.

The chemical analyses indicate a normal, unpolluted stream prior to the winery season and show that the addition of winery wastes created two areas of partial oxygen depletion. These areas lie in the section immediately above the Woodbridge Dam and in the tidal section already discussed, substantiating calculations from the physical data which indicate that the average pollution load of 163,000 will result in oxygen demands on the river distributed as follows:

River Area	Oxygen Demand Lb./acre/day
Above Woodbridge Dam	61
Woodbridge to Galt	40
Galt to New Hope Landing	53
New Hope Landing to — 5.4 miles	57

A value of 120 lb./acre/day is generally accepted as the maximum oxygen reabsorption at zero saturation. Streeter, in recent publications, has shown that aeration is directly proportional to the degree of oxygen deficiency (provided other factors remain constant) and this fact has been confirmed in experiments by Shaw (2). On this basis the demand of 57 lb./acre/day for the three-day period of flow below New Hope Landing could not be satisfied at saturations above 52 per cent, at which point an equilibrium between demand and reabsorption would be established. This value corresponds closely with actual observations of 46 to 60 per cent in that area.

Oxygen depletions in the lower river were not determined in 1935, but an average value of 13.6 p.p.m. oxygen consumed was observed at the Galt Bridge and the physical and chemical data of 1936 furnishes

a reliable means of estimating conditions below New Hope Landing in 1935; comparative calculations indicating that oxygen saturations of 24 per cent or lower probably extended over a considerable area during that season.

Aeration Factor.—The middle section from the Woodbridge Dam to the Galt Bridge serves as an excellent stretch of river for computation of an aeration factor. The channel is reasonably uniform, without diversions or dilution and the initial oxygen saturation below the dam is fairly constant. Oxygen demand values obtained at the Galt Bridge may be utilized to calculate the oxygen demand satisfied during the estimated time flow interval of 29 hours from Woodbridge Dam. In this section, the oxygen curve approximates a straight line so that for practical purposes, the average deficiency may be taken as half the sum of the initial and final deficiency.

For a 5-day demand of 5.6 p.p.m. an average depletion of 1.95 p.p.m. was noted at the Galt Bridge. The demand satisfied in the preceding interval of 29 hours at the normal rate of biochemical oxidation for the existing temperature would be 2.3 p.p.m. The initial deficiency below the Woodbridge Dam was 0.95 p.p.m. The initial deficiency plus the demand minus the final deficiency indicates reaeration of 1.30 p.p.m. at an average deficiency of 1.45 p.p.m. which is equivalent to 8.77 p.p.m. reaeration at zero saturation. Correcting this value to a 24-hour period we have 7.26 p.p.m. or 19.6 lb./acre foot or 110 lb. per acre of surface. The above calculations may be combined and expressed by the following formula:

$$A = \frac{130\ S\ W\ (I + D - F)}{T\ (I + F)},$$

where

A equals aeration factor at zero saturation in lb./acre/day,
W equals water depth in feet,
T equals time interval in hours between stations,
S equals p.p.m. oxygen at 100 per cent saturation,
I equals p.p.m. oxygen deficiency—initial,
F equals p.p.m. oxygen deficiency—final,
D equals p.p.m. oxygen demand satisfied between stations.

Applying this to the conditions observed we have:

$$A = \frac{130 \times 9.8 \times 5.6(.95 + 2.3 - 1.95)}{29\ (.95 + 1.95)} = 110 \text{ lb./acre/day.}$$

This formula may be restated to estimate downstream depletions if an aeration factor has been established:

$$F = \frac{130\ S\ W\ (I + D) - A\ T\ I}{130\ S\ W + A\ T}.$$

It is anticipated that further work will be conducted on reaeration in the Mokelumne River and other streams and these data will be discussed in more detail in a later publication.

Fungus Growth and River Appearance.—DeMartini noted the appearance of *Sphaerotilus*-like fungus growths in the river with winery

waste dilutions of 1/1300. Similar growths have been noted in greater abundance during subsequent surveys. The river also develops a typical dark appearance with a mirror-like cast during the winery season.

Effect on Fish Life.—Until recent years, the Mokelumne River has been noted as a fishing stream, black bass and salmon being the important species. During the past few winery seasons, dead fish have been observed by numerous people and the runs of migratory salmon have shown an alarming decrease. In the peak production year of 1935, practically no salmon came upstream, which indicates that a barrier may have been established in the lower river. This section is quite isolated and fish fatalities might not be reported, the principal reports of such losses coming from the vicinity of Woodbridge Dam.

In the 1936 season, a series of fish tests were conducted by placing bluegills, black bass and other species in cages submerged in the river at points above and below pollution. All the fish died in tests just above the Woodbridge Dam and heavy losses occurred near the upper end of the lake. The losses appeared to occur during short intervals of increased pollution load and are believed to have resulted from suffocation. Tests near discharge outlets seemed to indicate that oxygen depletion is the controlling factor rather than direct toxicity. No cage tests were made in the lower tidal area.

The fungus growth is irritating to the gills of fish and heavy deposits of fungus and sediment have frequently been observed on the gills. It is also probable that a high oxygen demand would result if the fungus is killed by sudden temperature changes, a condition that was observed during studies of pollution in the Eel River from dairy wastes. The possibility that winery wastes have a deleterious effect on aquatic organisms and fish foods should also be investigated. Along this line, it would seem that the observations of local people familiar with river and fishing conditions are extremely valuable. After all, we have a tendency to estimate the degree of pollution on a few simple tests, when in reality there may be many other factors deleterious to aquatic life of which we know little at the present time, the resulting effect of which may be noted by local observers.

Restriction of Winery Wastes.—As a result of the findings to date an order has been issued by the Division of Fish and Game prohibiting further discharge of still slops and other concentrated wastes to the river. Further studies will be conducted to determine whether additional restrictions will be required. Since the issuing of this order, the California Wine Institute has launched a program to assist their member wineries in solving the problem of satisfactory waste disposal. Whether this will prove to be evaporation, chemical treatment, filtration, land disposal or some other method has yet to be worked out.

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CANNERY WASTE AT PALO ALTO

By Ted R. Gregory and Jack H. Kimball

Presented before the Ninth Annual Conference of the California Sewage Works Association, April 24, 1937

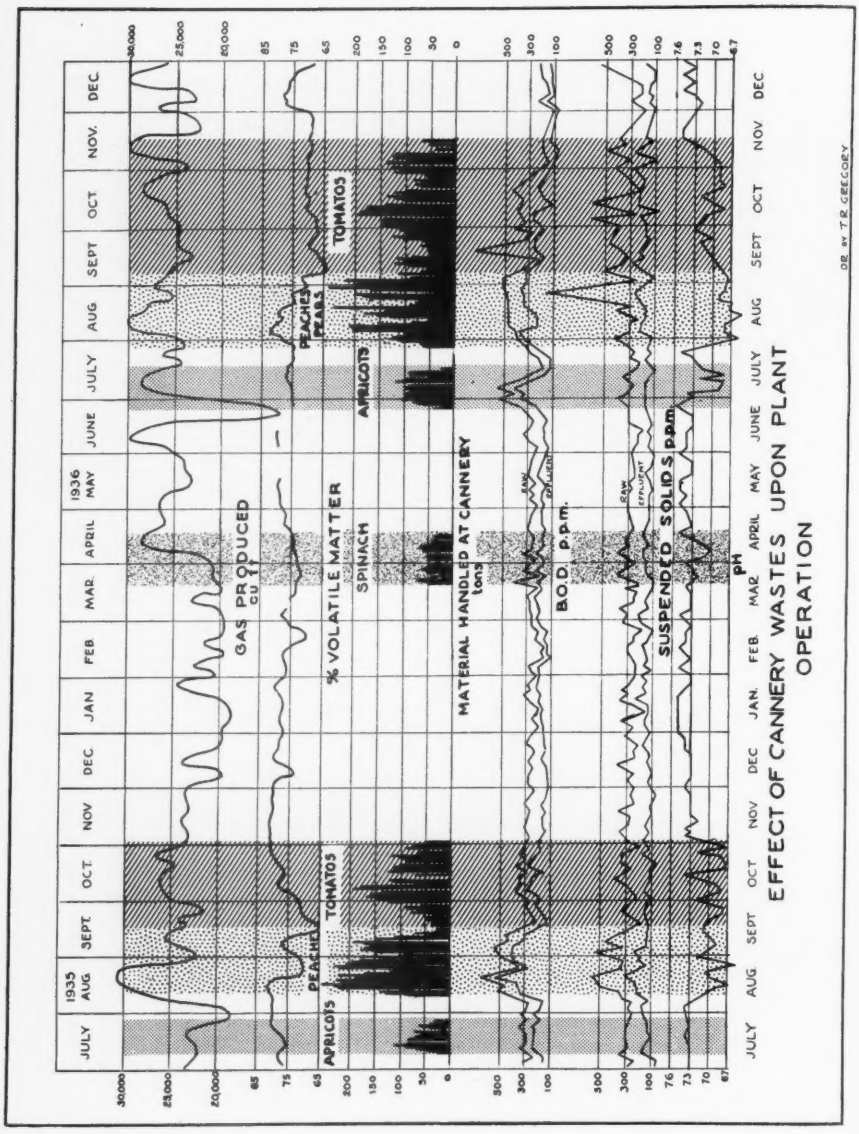
The cannery waste problem was realized directly after the Palo Alto Sewage Treatment Plant was put in operation on July, 1934. During each succeeding canning season the load on the plant has exceeded its designed capacity. The result of this overloading is indicated by an inferior effluent discharged into San Francisco Bay.

During this time we have had opportunity to run preliminary laboratory tests on the cannery waste and to note its effect on domestic sewage. The purpose of this paper, therefore, is to present as fully as possible our observations on the cannery wastes and their effect on the operation of the treatment plant; to enumerate preventive measures taken by the city to reduce the load upon the plant; and finally to show the strength and character of the cannery waste in comparison with normal domestic sewage, as indicated by the laboratory results.

Summary of Palo Alto Sewage Treatment Plant

Quantity and Character of the Sewage.—The average sewage flow for the past year has been 1.66 m.g.d. from a contributing population of approximately 20,500. The maximum flow has reached 3.00 m.g.d. which is the designed capacity of the plant. The character of the sewage during eight months of the year is purely domestic. The Sutter Packing Company operates four and one-half months of the year and is the only industry contributing trade waste to the sewage plant. During the 1935 season this cannery packed the following quantities of products: spinach, 1,200 tons; apricots, 960 tons; peaches, 5,000 tons; and tomatoes, 3,300 tons. The cannery operates from eight to twelve hours a day and employs a maximum of 500 men and women. On a full day run approximately 500,000 gallons of water are used.

Type of Treatment.—The Palo Alto Sewage Plant is the plain sedimentation type with separate sludge digestion. Plant equipment includes a ¾-in. mechanically cleaned rack, three 1,100 g.p.m. sewage pumps which lift the sewage 24 feet, and a 151,000 gallon circular clarifier. The clarifier has a theoretical retention period of 1 hour at the maximum designed rate of 3.00 m.g.d. The sludge is pumped to a 386,000 gallon concrete digestion tank with a fixed cover. This tank is provided with heating coils and maintains the sludge at a temperature between 90° and 100° F. The piping is arranged so that the contents can be circulated by the sludge pump. The final disposal of the effluent is by dilution in San Fransico Bay 1,000 feet off shore. Sludge is disposed of by drying and pulverizing for fertilizer in the city's parks.


EFFECT OF CANNERY WASTES UPON PLANT OPERATION
JULY 1935 AUG SEPT OCT NOV DEC JAN FEB MAR APRIL MAY 1936 JUNE JULY AUG SEPT OCT NOV DEC
GAS PRODUCED cu ft
% VOLATILE MATTER
MATERIAL HANDLED AT CANNERY tons
B.O.D. p.p.m.
SUSPENDED SOLIDS p.p.m.
pH
APRICOTS PEACHES TOMATOS
SPINACH
APRICOTS
PEACHES PEARS
TOMATOS
RAW
EFFLUENT
DR. W. T. R. GREGORY

Effect of Cannery Waste on Plant Operation

Soon after the plant was placed in operation the operator * was faced with the problem of freeing the clarifier of large quantities of halved and sliced peaches. The peaches, being at the fermentation stage, floated on the surface and at times reached a depth of two feet. The skimming device was naturally inadequate for such a load and consequently the peaches had to be removed by the slow process of hand skimming. During this peach canning season the operators were kept busy practically day and night at this work. The peaches were skimmed into the scum trough from which they went to the sludge pit and were them pumped to the digester along with the raw sludge drawn from the bottom of the clarifier. Tomato season followed the peach season, and as all waste tomatoes were washed down the sewer, the plant was soon flooded with tomato skins. The skins, in contrast, settled to the bottom of the clarifier and were pumped to the digester. Since the tomato skins are not affected by the process of digestion and being lighter than the sludge, they formed a dense mat from two to four feet thick on the surface of the digester and are still there after two years. Seven months after the plant was put in operation the contents of the digester had become ripe enough to begin active digestion. For the next three months a great deal of foaming was experienced along with extremely high gas production, the average daily production for the tenth month of digestion being 38,430 cu. ft. with a maximum of 52,000 cu. ft. which was equivalent to 2.5 cu. ft. per capita per day. It is reasonable to believe that this tremendous activity prolonged over a three months' period may be blamed on the large quantities of peach waste. The thick mat, formed by the tomato skins on the surface of the rapidly digesting sludge, probably prevented a smoother digestion operation. During this first year, therefore, operation of the plant was made extremely difficult because of excessive cannery waste.

Preventive Measures and Their Effects

It was believed that a large part of this canning waste could be prevented from entering the sewer at the cannery itself. Therefore, cooperation of the Sutter Packing Company was requested by the City Engineer. There is a city ordinance for the purpose of regulating all wastes discharged into the city's sewers. However, reference to this ordinance was not necessary as the packing company cooperated to the fullest extent in the attempt to prevent solid wastes from entering the sewer. In this respect the operators as well as the city, are very fortunate in having Mr. Carmein as superintendent of the Sutter Packing Company. The following improvements were made at the cannery: Fine screens were installed on all floor drains and provision made for their regular cleaning; a "Cyclone Beater" having a 1/16 in.

* Since the writers were not connected with the plant during the first year of its operation the following information covering this period was obtained from the paper written by Harvey O. Banks and published in the January, 1936, issue, *Sewage Works Journal*, which was presented at the Fall 1935 meeting of this Association.

screen was acquired and all waste tomatoes were passed through it to remove as much of the fibrous material as possible; a continuous operating, mechanical screen was designed and installed by the packing company through which all the waste water flowed; finally, provision was made to collect all the screenings removed from the waste water in the above three ways and to truck them to the city garbage dump where they are buried.

As a result of these "preventive measures," the 1935 canning season did not inconvenience or disrupt the operation of the sewage treatment plant. Practically no solid fruit was noticed in the sewage. Peach pulp did collect on the surface of the clarifier but the skimming arm was able to clear the tank in four or five hours. During the 1936 tomato season quite a bit of trouble was experienced because the sewage pumps were clogged with tomato skins. The skins would work their way between the casing and the runner and roll up into tight wads. This trouble did not occur during the 1935–36 tomato season. The probable reason for this trouble is that the clearance between the runner and wearing ring had increased by wear so that the fresh water seal no longer functioned to keep out such material. The pumps soon became overloaded and it was necessary to remove the entire upper half of the pump casing to remove the skins.

In spite of these screens and beaters, some solids still entered the sewer, caused no doubt by operation. During one visit to the cannery during the peach season, the operator noticed that all waste material on the floor was swept into the sewer past the screen by one of the workers. Another waste from the cannery which caused much trouble at the plant was wood from broken packing boxes. The digester operated normally throughout the canning season, and the only apparent effects on it were a drop in pH to 7.0 and a marked increase in gas production. The maximum daily amount of gas produced during the peach season was 37,000 cu. ft. as compared with the yearly average of 25,000 cu. ft. Although operation of the plant was not inconvenienced by the cannery wastes, the efficiency of the plant was greatly reduced. In other words, the effluent discharged to the bay was stronger in organic load and suspended matter than the ordinary domestic raw sewage. If this condition is permitted to exist four and one-half months of the year it would seem unnecessary to treat the sewage during the remaining part of the year. Table II compares the plant effluent produced when the cannery is working with the regular domestic effluent.

1937 Canning Season—What to Expect.—During the past winter the Sutter Packing Company has remodeled the interior of the cannery, increased its floor space, and has acquired much new machinery and equipment. As a result the cannery is an up to date packing plant with increased capacity of 10 per cent. By comparing with the pack for the past two years, the sewage plant can expect an equivalent increase in canning waste load. Also since the capacity of the packing plant has been increased, one can expect a more concentrated canning waste reaching the sewage plant than hertofore.

What Should Be Done and To What Extent.—The problem which faces the Palo Alto Plant is to determine what quality of effluent should be produced. So far, no complaints have been received during the canning season, since San Francisco Bay is big enough to take care of the extra load. However, since the sewage plant has been an expensive project, it seems that, if the city is going to gets its money's worth the plant should be made to produce an effluent of consistent quality all year round. Therefore the quality of effluent should be that produced during the eight months of the year when only domestic sewage is received at the plant. In order to bring this about additional treatment would be necessary either at the cannery or at the sewage plant. Since the scope of this paper does not cover the type and cost of such a treatment, it will not be discussed here.

Strength and Character of Cannery Waste

At the beginning of the 1936 spinach canning season, in April, a definite schedule was set up for sampling and testing the wastes. This was followed throughout the pack of apricots, peaches and pears, and tomatoes in succession. As a result, some data were obtained, and although quite inconsistent at times, they enabled us to make a rough estimate of the strength of the canning wastes expressed in biochemical oxygen demand. The comparative results are shown in Table I.

Table I.—*Character of Cannery Wastes at Palo Alto 1936 Season*

Type of Waste	Quantity Handled			Waste Water Gal./ Ton	No. Samples Tested	Temp. °C.	pH	Suspended Solids p.p.m.	Oxygen Cons. p.p.m.	B.O.D. p.p.m.		Population Equiv.	
	Total Tons for Season	Mean Tons/ Day	Maximum Tons/ Day							Max.	Mean	Max. Persons	Persons/ Ton Mean
Spinach	1173	49	71	8100	4	45	7.3	90	—	810	730	20,800	290
With lye treatment					1	—	—	—	2000	460	380	5,900	49
Apricots	1386	77	120	2500			over						
Without lye treatment					1	30	7.6	260	700	210	200	3,100	26
Peaches	4279	97	208	2600	7	31	over 7.6	600	2000	over 1500	1350	37,300	179
Pears	771	20	41	2580	—	—	—	—	—	—	—	—	—
Tomatoes	5800	88	196	3600	6	32	6.6	270	1160	1200	990	35,300	180

Schedule of Tests.—When possible a series of tests were run on the same days that similar tests were run on the raw and settled sewage at the plant. These regular test days are Tuesday and Friday, but many times the cannery would not be working so that samples were

taken on other days. The schedule included the following laboratory tests: B.O.D., suspended solids, temperature, and pH. As a confirmatory test, oxygen consumed by permanganate was determined as often as possible, on both cannery waste and sewage.

Method of Sampling.—Since there is no standard method for sampling of trade wastes, it was important to decide on how to obtain a sample that would be representative of the waste discharged into the sewer for any one day. During the spinach season it was attempted to get a composite sample for a day's pack. With the cooperation of the plant superintendent a worker was instructed to take a sample (300 ml.) every hour. The next morning this composite sample was taken to the sewage plant and was tested along with the composite samples of the raw and settled sewage. After several weeks, however, this method of sampling was abandoned since the temperature of the spinach waste, 45° C., was too high to permit it to be retained as a composite sample. Also the sampling technique could not be depended upon. For the rest of the season, therefore, catch samples were taken at 11:00 A.M. which according to the superintendent was the time when the cannery was most likely to be running uniformly.

For spinach, a catch sample is probably fairly representative, since the cleaning and wilting process are continuous and no chemicals are used. There are discharges of hot, clear water when the cookers are periodically opened. Samples were taken in between these discharges.

It is more difficult to get a representative sample of apricot waste since apricots are canned either with or without their skins. A lye process removes the skins and, therefore, increases the organic and chemical content of the waste water. The character of the waste when a catch sample is taken depends upon which one or both of the above methods is in operation.

Peaches go through a more consistent process since it is necessary to remove the fuzz and skin in the lye tank where most of the organic matter and waste water originates.

Pear season is coincident with the peach season, but no tests were run on this waste as the pears were packed at night.

Tomatoes produce a waste which is more dependent on the amount of spoiled and waste fruit than in the variation of the canning process, since all waste tomatoes are put through the "cyclone beater" and the liquid wasted to the sewer.

It is realized that this method of sampling can not be depended on as truly representative, but will serve the purpose in this preliminary investigation of canning wastes and their effects on the Palo Alto Sewage.

Laboratory Procedure

B.O.D. tests were run following standard methods, with one exception. Due to the fact that our plant is not equipped with an incubator, we have used for this a crockery waste jar filled with water at room temperature. Daily B.O.D. tests cannot be run due to the limited

amount of equipment and storage space available. Bi-weekly tests so far have proven adequate.

Oxygen consumed tests were run in accordance with standard methods, using a strong solution of permanganate and digesting for half an hour. Few checks on this method were run from day to day due to the consistency of results.

Suspended solids are run using a Gooch crucible, and using a 50 or 100 ml. sample, depending upon the amount of suspended matter present. Temperature of the sewage was taken at 11:00 A.M.

Method of Computation

Population equivalents of the various wastes were calculated using the mean B.O.D. values, the number of gallons of water used, and number of tons of materials handled. Using the value 0.162 lb. of B.O.D. per capita and substituting in formula: B.O.D. (p.p.m.) $\times$ 8.33 $\times$ (gal. water used/ton) $\div$ 0.162 = no. persons/ton or the population equivalent. Maximum and mean values for each waste were calculated. The population equivalents per maximum number of tons handled per day were also calculated as these would affect future design. The pounds of B.O.D. per capita were figured using the 1936 average flow of 1.66 m.g.d., B.O.D. of 240 p.p.m., and a population of 20,500.

$\frac{240 \times 8.33 \times 1.66}{20{,}500} = 0.162$. This agrees with an average value of 0.167 pounds per capita used by Reinke.*

From the values of the mean population equivalents, it is seen that

Table II.—*Variation of Plant Effluent Due to Type of Cannery Waste, 1936 Season*

Type of Waste	Mean % Increase in Flow	Mean Values of B.O.D.					Mean Values of Suspended Solids				
		Waste	Raw	Effluent	% Reduced in Raw	% in Excess of Domestic Effluent	Waste	Raw	Effluent	% Reduced in Raw	% in Excess of Domestic Effluent
Domestic	0.0	0	240	165	31	0	0	290	140	52	0.0
Spinach	21	770	295	190	36	110	90	320	160	50	110
Apricots: With lye treatment		380									
Apricots: Without lye treatment	19	200	430	330	23	170	260	250	140	44	0
Peaches and Pears	31	(Peaches only) 1350	420	300	28	180	(Peaches only) 600	450	200	56	140
Tomatoes	18	990	350	220	37	140	270	325	150	54	107

* Bulletin 28. California State Division of Water Resources.

there is a load on the plant from the wastes alone equal to and greater than that furnished by the domestic sewage. However, from Table II which shows the variation of the plant effluent with different types of cannery wastes, the B.O.D. and suspended solids tests indicate that this load is less than twice the strength of average domestic sewage.

According to our results, peaches, pears, and apricots are the strongest of the wastes, followed by tomatoes and spinach. In the case of the first three, the effluent is worse with regard to oxygen demand than ordinary domestic raw sewage. Tomatoes and spinach also produce an effluent which is very poor in quality.

SEWAGE DISPOSAL IN THE PACIFIC NORTHWEST *

By Carl E. Green

State Sanitary Engineer of Oregon

The states of Idaho, Oregon and Washington, situated as they are in the northwestern corner of the United States, have many things in common. Their principal industries are based upon timber, agriculture, fisheries, stock raising and mining. Nevertheless, each is different from each other and within the confines of each state one finds considerable variation in topography and climate. The Cascade Mountains divide both Oregon and Washington into two distinct portions—(1) the western portion which is well supplied with precipitation except during mid-summer and in which extremes of temperature are usually lacking, and (2) the eastern portion which is arid to semi-arid except in the high mountains where heavy snows fall, and in which low winter and high summer temperatures are common. Idaho's climate resembles that of eastern Oregon and Washington. Along the coast line of Oregon and Washington considerable difference exists. The Puget Sound provides navigable water ways to Washington's two largest cities, Seattle and Tacoma. The Olympic peninsula of Washington probably receives more precipitation than any other area of comparable size in the United States. No large cities are to be found on the Oregon coast line (Portland being 105 miles up the Columbia River.

Slowly melting snows and glaciers in the Columbia basin together with many, mammoth lakes in Washington and Idaho act as flow regulators of the Columbia River and its tributaries. Winter and spring flood flows are not only greatly reduced but fairly uniform summer stream discharges are thus maintained, to the benefit of sewage disposal as well as irrigation, power production and flood control. The Columbia River is exceeded in size in the United States only by the Mississippi River. Offhand it would seem logical to expect that sewage disposal by dilution would be widely practiced in an area such as this having so many large streams and convenient ocean water. Because of the abundance of water and because these three states are relatively sparsely settled, sewage treatment has lagged behind that in some other more populous areas of the country.

In recent years a sewage and industrial waste treatment program has made a significant start. It seems probable that the ultimate result will be the prevention of serious pollution before restoration of streams becomes difficult if not impossible to accomplish.

Idaho had a population of 445,000 in 1930 and an estimated population of 448,000 in 1935. Boise, the state's capital and largest city, has a population of 21,000. Sewers have been constructed in cities and

* Presented before the Ninth Annual Conference of the California Sewage Works Association, Stockton, April 24, 1937.

villages which have a combined total population of 173,000. Only two towns have complete treatment plants—Rupert and Meridian. Many of the small towns have old, obsolete septic tanks. The largest cities, Boise, Lewiston, Pocatello, and Twin Falls all discharge raw sewage into the Snake River. Several cities and many irrigation districts use Snake River water, but a fairly high dilution is provided by the Snake.

The 1,563,000 population of Washington just exceeds the combined population of Oregon and Idaho. Until 1936, only one complete sewage treatment plant was in operation in Washington—at Walla Walla. During the past year several plants have been under construction in the Yakima River valley. The largest plant, at Yakima, is noteworthy in that its flow varies from 4.2 m.g.d. (190 gal. per capita) during December, January, February and March to a maximum of 18 m.g.d. during the irrigation season. High ground water and infiltration account for the high flow. The Yakima plant provides for primary treatment and chlorination during the summer. This plant, as well as others in the Yakima valley, is being constructed principally to reduce pollution of irrigation water which in turn pollutes community and farm wells throughout the irrigated districts. A sanitary survey of the Yakima River by the Washington State Health Department showed sewage pollution to be the cause of the high incidence of typhoid fever which has prevailed in the area for many years.

Primary plants have been or are being constructed at Selah, Zillah and Wapato. Colfax has recently let contracts for the construction of a complete trickling filter plant. Plans have been prepared for plants at Lynden, Dayton and Ellensburg. In the western portion of Washington very few sewage treatment plants have been built. Seattle has been working toward the elimination of all sewage from Lake Washington by construction of interceptors and pumping stations to divert sewage to Puget Sound.

Wastes from pulp and paper mills and canneries have given the state of Washington much concern. Paper mill wastes are discharged primarily into salt water but damage to shell-fish growing areas by sulphite waste liquor has been claimed by the shell-fish industry. Canneries are increasing in number and capacity both in Washington and Oregon, and disposal of their seasonal wastes creates a serious problem, especially since cannery operations usually coincide with low stream flows.

Though 62 per cent of Washington's population lives in cities and towns served by sewerage systems, only 10.6 per cent of this population or 6.6 per cent of the state's total population is provided with some kind of sewage treatment.

Oregon, with a population of 1,000,000, has led both Washington and Idaho in sewage treatment, since ten of its cities now have complete treatment plants (1 intermittent sand filter, 3 activated sludge, and 6 trickling filter plants) in operation. In addition, four cities have modern, primary treatment plants and construction has just started in another. Nineteen others have septic tanks. Chemawa and Warm

Springs Indian Reservations and the Multnomah County farm have adequate, complete treatment plants. In addition, septic tanks are in use at eleven institutions.

The eastern and southwestern portions of Oregon are reasonably well provided with sewage treatment plants, but the Willamette Valley is not. Though the Willamette Valley contains only 12 per cent of the area of the state, nevertheless it has 71 per cent of the state's urban population. It is in this valley that the next major activity in sewage treatment should take place. When it does, the relatively small proportion of the state's urban population now provided with adequate treatment facilities will be greatly increased.

Portland, as well as being the most important commercial city of the Willamette Valley and the State, is also the key city in so far as sewage treatment is concerned. Its problem of sewage treatment is complicated by the fact that the city now discharges combined sewage into the Willamette River through about 55 outfalls on both sides of the stream. A few outfalls empty into Columbia Slough on the north of the city. The most difficult and costly part of the Portland project is that of intercepting sewers, under-river crossings, pumping stations, and a tunnel necessary to collect and convey the sewage to a treatment site near the Columbia River. The estimated cost is $8,240,000. The proposal provides for primary treatment and discharge into the Columbia River rather than complete treatment and discharge into the Willamette River.

Industrial wastes create problems in many sections of Oregon; wastes from pulp and paper mills and canneries are among those most difficult to treat. A start is being made this year in cannery waste treatment. Of the many processes for the treatment and recovery of by-products from waste sulphite liquor, none so far has seemed economically attractive for Pacific Northwest mills. Sulphite liquor wastes discharged into the Willamette River have an equivalent population load on the stream which exceeds the total urban and rural population load of the valley. Wastes from flax retting plants, woolen mills, meat packing plants, tanneries, and many other industries add to the organic load of the Willamette River.

Except in a few instances where water supplies and fisheries are concerned, the economic approach to the problem of stream cleansing in Oregon is subordinate to the esthetic reasons for waste treatment. In this respect a fundamental difference may be noted when comparing stream purification activities with those in most other parts of the country. Public water supplies are not involved by stream pollution to any great extent and it is unlikely that they will be for a long time to come. Preservation of the fishing and recreational values of the state's streams and lakes as one of the state's most treasured resources is uppermost in the minds of those who have furthered the cause of sewage and waste treatment.

The same general approach to the problem also prevails in Washington and Idaho, but a direct correlation between stream pollution and

public health has been demonstrated in some parts of both of these states. In Idaho more public water supplies may be affected by stream pollution than either Oregon or Washington, especially if population and industries should increase greatly in the Snake River Valley.

With a few exceptions, stream pollution in the Pacific Northwest has not yet reached a critical point. The Willamette River at Portland during late summer and early fall presents an effective barrier for the passage of salmon up stream, *i.e.*, practically zero dissolved oxygen for about three miles. The Yakima River of Washington is being freed of excessive pollution. The task before the Pacific Northwest states is the elimination of the few critical conditions which exist at present and the prevention of further excessive burdens of pollution on the many streams in the area.

OBSERVATIONS ON THE RATE OF OPERATION OF HEATED DIGESTION TANKS *

By Walter A. Sperry

Superintendent, the Aurora Sanitary District, Aurora, Illinois

For the past two years the digester operation problem at the Aurora plant has been increasingly difficult. It reached an emergency peak in 1937 as indicated by the following situation.

This year the digesters were discharged to the beds April 15th, 19th and 27th. Under the conditions existing in the years 1931–1935, inclusive, when we handled approximately 50 tons of primary sludge per month, with gas evolution of approximately 30,000 cu. ft. per day, the digesters would not have been discharged to the beds short of August or September. In May, however, we were compelled to force clean the beds and again discharge digesters on May 26th, June 1st and 7th. We now have beds with sludge too wet to remove and our digesters are again filled to the point where our supernatant liquor has disappeared.

During the month of May, 196 tons of sludge were pumped to the digesters. In this same month we produced 50,000 cu. ft. of gas per day. Between May 8th and 26th, a period of 19 days, we averaged 61,000 cu. ft. of gas per day, with four days within this period running from 70,000 to 78,000 cu. ft. per day. During this interval the sludges bulked in the digesters, due to gas flotation, to a sludge density as low as 4 or 5 per cent. Under this condition 1,000 lb. of sludge occupied 350 cu. ft. Under the conditions existing in the earlier years, when 50 tons of sludge per month was discharged to the digesters, the sludge concentration averaged 9 per cent, and 1,000 lb. of sludge occupied 180 cu. ft.

In the meantime desperate measures had to be adopted, in May and again in June. The secondary tank was cut out of service, part of the raw sewage flow was discharged to the river, after screening and grit removal, to reduce the load sufficiently to allow the digesters to quiet down. This procedure allowed the digesters to "gas out" and the sludges to thicken enough for discharge of a sufficient amount to the beds to make the cleaning worthwhile. In the meantime we recirculated between the clarifiers and the digesters approximately 90,000 lb. of sludge. The sludge accumulated in the clarifiers to a depth of nearly one foot. We gained control of the situation fairly well the latter part of May and again started off with clean digesters and clean clarifiers, but in the first eleven days of this June we again averaged 50,000 cu. ft. of gas per day and have handled, through the 11th of June, 46 tons of sludge to the digesters.

Based on Mr. Greeley's plan of evaluating digesters we added 0.9 lb. of solids per cu. ft. of digester in the years 1931–1935. For the month of May, 1937, we added 3.2 lb. of solids per cu. ft. of digester.

* Presented Before the 14th Annual Convention of the Illinois Association of Sanitary Districts, Waukegan, Illinois, June 17, 1937.

The gas evolution per sq. ft. of area increased from 4.2 cu. ft. per day in the former period to 8 to 10 cu. ft. in 1937. This general picture of present operating conditions indicates the impossible conditions under which we are attempting to operate. A laboratory study of the situation confirms the advice of both Mr. Wisely and Dr. Fischer. It indicates that we must immediately shift our operating scheme to the two-stage plan. This laboratory set-up compares single-stage with double-stage digestion, operating mathematically in parallel with plant conditions from day to day, and indicates the present capacity will likely be adequate for the present loadings now being received. Drawing-board studies indicate that some rather simple and inexpensive changes will allow us to operate on the two-stage principle now practised in the Elmhurst plant.

It will be recalled that Aurora has three digesters of the original Dorr bridge type, 50 ft. square and 16 ft. deep, and containing 41,000 cu. ft. per digester. On the design basis of 67,000 this provided 1.85 cu. ft. per capita. On the basis of the present population served, of 50,000, we have a capacity of 2.5 cu. ft. per capita. This design was made in 1926–28, and the capacity provided was probably more generous than for later designs.

Since 1930 we have frequently had over-full digesters and occasional periods of over-flowing. We have never had an acid condition of true "foaming." The over-flowing phenomena was due to over-feeding and the bulking effect of too much gas evolution. This condition was always corrected by reducing the load or resting the digesters.

In 1936, a study of our experiences as far back as February, 1932, clearly indicated some of the reasons for the difficult situation now existing. This study has been condensed in Table I.

TABLE I

	Tons Dry Sludge per Month	Aver. % Solids Bottom Layer	Cu. Ft. Occ'pd in Dig. per 1,000 lb. Sludge	Aver. % Solids in Dig.*	Cu. Ft. Occ'pd in Dig. per 1,000 lb. Sludge	Aver. Gas Produced per Month, Cu. Ft.	Cu. Ft. Gas per Ton of Dry Sludge Added	Cu. Ft. Gas per Day	Cu. Ft. Gas Released per Sq. Ft. of Area	No. of Digester Cleanings	
										Total	Per Year
Period 1 14 months:											
2/32–3/33	56.0	15.8	113	9.4	180	987,300	17,600	32,910	4.38	2	1.7
Period 2 34 months:											
4/33–1/36	63.3	9.4	180	7.1	230	1,020,000	16,100	34,000	4.53	9	3.2
			27.8% increase over Period 1								
Period 3 12 months:											
2/36–1/37	84.53	8.2	200	6.5	250	1,358,000	16,000	45,260	6.03	4	4.0
					38.8% increase over Period 1						
					8.7% increase over Period 2						

* = Average per cent solids above bottom layer.

The study covers three periods from February, 1932, through January, 1937. In the first period of 14 months we operated under the normal plan of single-stage digestion by discharging sludge equally to each of the three digesters daily. During this period we averaged 56 tons of sludge per month and carried 9.4 per cent solids content in the body of the digesters. One thousand pounds of sludge occupied 180 cu. ft. We averaged 33,000 cu. ft. of gas per day, which was equivalent to 4.4 cu. ft. per day per sq. ft. of surface area. During this period we discharged sludge to the beds at the rate of 1.7 times per year.

In the second period of 34 months, from April, 1933, through January, 1936, we operated the digesters on a semi two-stage plan by pumping all of the sludge on the first day into the first digester, on the second day to the second digester and so on. This gave each digester a two day rest period. The average tons of sludge per month increased to 63.3 tons or 13 per cent. The concentration of solids in the body of the digester averaged 7.1 per cent so that 1,000 lb. of sludge occupied 230 instead of 180 cu. ft. We, therefore, lost 28 per cent digester capacity. The gas evolution remained at 34,000 cu. ft. per day but the rate of gas release per sq. ft. of area increased from 4.4 in the first period to 5.7 cu. ft. in the second period. Table II shows that 43 per

TABLE II

	Period 1		Period 2			Period 3		Period 3 on Basis of Period 2		
	14 Months: 2/32–3/33		34 Months: 4/33–1/36			12 Months: 2/36–1/37				
	Cu. Ft. Gas per Day	Cu. Ft. Gas Released per Sq. Ft. of Area	Cu. Ft. Gas per Day	%	Cu. Ft. Gas Released per Sq. Ft. of Area	Cu. Ft. Gas per Day	Cu. Ft. Gas Released per Sq. Ft. of Area	Cu. Ft. Gas per Day	%	Cu. Ft. Gas Released per Sq. Ft. of Area
Dig. No. 1.....	10,120	4.1	14,500	42.7	5.7	14,530	5.8	19,300	42.7	7.7
Dig. No. 2.....	12,070	4.8	11,900	35.0	4.7	15,570	6.3	15,800	35.0	6.3
Dig. No. 3.....	10,720	4.3	7,600	22.3	2.9	15,160	6.1	10,160	22.3	4.1
Totals.....	32,910		34,000	100.0		45,260		45,260	100.0	

cent of the total gas was discharged from the digester on the day of receiving the day's sludge accumulation. While the rate of gas evolution in each digester dropped to 4.7 and 2.9 cu. ft. per square foot of area on the second and third day, this period was not long enough for the digester to quiet down before the third day when it was again increased to the 5.7 rate by a fresh addition of sludge. The effect of this "bulking" of sludge, due to gassing rate, increased the need for discharging sludge to the drying beds about 100 per cent, i.e. from 1.7

times per year for the first period to 3.2 times per year for the second period.

In the third period, covering the 12 months from February, 1936, to January, 1937, inclusive, the sludge per month increased from 63 to 84 tons, or 33 per cent. During this period we changed from the intermittent feeding plan back to the straight one-third per digester plan of the first period. The concentration of solids in the body of the digester decreased again, from 7.1 to 6.5 per cent, so that the volume occupied per 1,000 lb. of sludge changed from 230 cu. ft. for the second period to 250 cu. ft. for the third period. This was an additional loss of storage capacity of 8.7 per cent and a total loss of 39 per cent over the first period. During this period gas evolution increased to 45,260 cu. ft. per day and the rate of gas release per sq. ft. of area per day from 4.5 to 6.0 cu. ft. The number of digester cleanings per year increased to four.

The average conditions do not fully tell the story, since the average maximum day during 1936, the time of the third period, gave 64,000 cu. ft. of gas per day. There were 78 days in 1936 when gas production was above 55,000 cu. ft. against our average of 45,000 so that the rate of gas release was frequently greater than 6.0 cu. ft. per sq. ft. of area per day and many days approaching 10 cu. ft.

Study of Tables I and II will further indicate that the quality of sludge remained about the same as to gas-producing qualities. For each of the three periods under study the volume of gas per ton of dry sludge added, remained at approximately 16,000 cu. ft.

Table III presents Aurora's experience, without respect to method of digester operation, and compares the first four months of each of the years 1931 to 1937, inclusive.

Note that the results for the years 1931 to 1935, inclusive, were of approximately equal value. The sludge rate per month remained at approximately 50 tons, the daily sludge to the digesters averaged 1.54 tons and the gas rate per day was approximately 28,000 cu. ft. The gas rate per ton of dry sludge added was 18,800 cu. ft.

In 1936, however, the sludge rate jumped from 1.54 tons per day to the digesters to 2.49, or 61.7 per cent increase. The gassing rate increased from 28,000 to 43,000 cu. ft. per day, or 53 per cent. The gas rate per ton of dry sludge added remained at 18,800 cu. ft.

In 1937 the daily tons of sludge to the digesters increased another 21 per cent over the 1936 period. The rate per day remained at about 43,400 cu. ft. The rate per ton of dry sludge added dropped to 11,700 cu. ft. per day, due to the fact that 19 per cent of the sludge addition to the digesters was from the newly installed secondary settling basins and also due to the shorter digestion period. In 1937 the Aurora plant, therefore, faces not only a 20 per cent increase in primary sludge but a large additional increase of secondary sludge not heretofore handled. This more than doubles the loading received in the years 1931 to 1935, inclusive, and again indicates the necessity of shifting from single-stage to two-stage digestion.

TABLE III

	1931		1932		1933		1934		1935		1936		1937			
	Tons Prim. Sludge	Cu. Ft. Gas	Tons Prim. Sludge	Cu. Ft. Gas	Tons Prim. Sludge	Cu. Ft. Gas	Tons Prim. Sludge	Cu. Ft. Gas	Tons Prim. Sludge	Cu. Ft. Gas	Tons Prim. Sludge	Cu. Ft. Gas	Tons Prim. Sludge	Tons Sec. Sludge	Total Tons Sludge	Cu. Ft. Gas
Jan.	46	1,017,650	42	691,090	39	854,300	52	1,134,400	53	1,008,600	94	1,536,100	98	17	115	1,127,800
Febr.	44	818,900	50	846,200	28	587,900	46	943,400	56	969,900	75	1,321,700	91	15	106	1,255,700
March	53	930,520	40	798,200	26	634,200	60	1,025,300	47	765,400	58	1,115,300	94	23	117	1,740,900
April	52	909,940	47	953,900	27	492,100	78	1,146,700	39	655,200	75	1,275,100	80	33	113	1,146,400
Total	195	3,677,010	179	3,289,300	120	2,568,500	236	4,250,000	195	3,399,100	302	5,248,200	363	88	451	5,270,800
Per Day	1.62	30,400	1.48	27,180	1.0	21,400	1.97	35,400	1.62	28,300	2.49	43,370	3.02	0.73	3.76	43,900
Cu. ft. gas per ton of sludge		18,810		18,310		21,400		18,000		17,470		17,400				11,660

We conclude this brief discussion by stating:

a. That contrary to the statements of available census agencies that there has been no marked population increase—there must have been. There is a housing shortage. Every factory and store has increased its working force. Some plants have imported a number of new men into their organization. All of this indicates increased population.

b. While no new industries have been established, nor is there evidence of any additional industrial waste not heretofore received, we are certain that living conditions are markedly better and that people are eating richer foods. We have no other way of accounting for the increased loadings.

c. Flow conditions have remained about the same and the quality of sewage, as received, has not markedly changed, which again presents contradictory evidence.

d. Despite the inability to explain the increased loadings there are in evidence both the volume of sludge to be handled and the amount of gas produced.

e. The comparative experiences discussed seem to prove a conclusive relation between the rate of gas release and the working capacity of our digesters. This experinece indicates that if the gassing rate per square foot of area much exceeds 4.5 cubic feet per day that undue bulking takes place with subsequent loss of storage capacity.

f. This, in turn, because of thinner sludges, affects the capacity of the beds to dry the sludge.

g. It suggests that digester design must take into account the relation of height to depth. It further suggests that the wisdom of computing the cubic feet per capita capacity on but 75 to 80 per cent of the digester volume due to necessary room for scum and supernatant liquor.

Editors Note.—Mr. Sperry's data warrant study because of the careful records he has kept, particularly with reference to the rate of digester operation (sludge feed and gas production) as correlated with moisture content of sludge. Is the decrease in moisture content of sludge in 1937 caused by (1) the increase in gas rate, as stated in "*e*" above; (2) the shortened digestion period in 1937; or (3) the presence of secondary sludge in the digester in 1937? Mr. Sperry, in "*e*" and "*g*" above, is inclined to ascribe the change in sludge moisture primarily to the increase in gas rate from 4.5 cu. ft. per day per sq. ft. tank area to 6.0 and "on many days approaching 10.0." It seems to the writer that gas rate is more likely an effect rather than a cause—and that factors (2) and (3) are the causes. However, if gas rate can be used as a measure of moisture content of sludge, the data he has presented ought to be of great practical value both to the designing engineer and the plant operator. It is hoped that other operators of separate digestion tanks will forward an account of their experiences and comments on the interesting points raised by Mr. Sperry. Such discussion will be published promptly in *This Journal*. F. W. M.

THE EFFECT OF INDUSTRIAL WASTES ON SEWAGE PLANT OPERATION *

By John C. Geyer

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The problems which arise when industrial wastes are treated in municipal sewage disposal plants are numerous and complicated. If there is an absolute rule governing these problems it is the rule that each is different and must be solved individually. It is, however, possible to set down certain general principles which guide in attacking the operating difficulties that result from the presence of industrial wastes in domestic sewage.

The effect of industrial wastes on sewers will not be considered here but the discussion confined to those things which affect only the operation of treatment plants. The definition of the word operation must be extended to include the performance of such steps as may be necessary to regulate the discharge of certain industrial wastes at the factory. If some wastes were not controlled at their source it would be impossible to operate many municipal treatment works. Furthermore, this paper will be confined to the effect of wastes upon the three common processes used for treating sewage: sedimentation; aerobic biological treatment of the settled liquid; and anaerobic digestion of the sludge. The conditions which must be controlled in plant operation will be outlined and the effect of industrial wastes on these fundamental operating requirements discussed.

In order to operate a sewage treatment plant successfully in the presence of industrial wastes the following things must be controlled:

1. The character of the sewage which comes to the plant.
2. The character of the sewage or sludge as it is introduced into the various treatment devices.
3. The temperature at which sludge is digested.
4. The hydrogen-ion concentration in all biological processes.
5. The seeding with proper type and amount of organisms in biological devices.
6. The balance between oxygen supply and oxygen utilization in aerobic processes.
7. The distribution of treatment load between the various processes.

Of these seven factors the character of the sewage which comes to the plant is the most important and the most difficult to control. When the character of the sewage is abnormal and variable, the operator must use all the resources at his command to attempt to control the other six variables so that the plant will continue to function.

This discussion will be divided into two principal parts, first, dealing

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with regulation of the character of the sewage, and second, dealing with operation of the sewage works.

Regulation of the Character of Sewage Containing Industrial Wastes

For satisfactory operation of plants involving biological treatment the sewage should be:

1. As uniform in composition and quantity as possbile, and free from all sudden dumpings of the more deleterious industrial wastes.
2. Not highly loaded with suspended matter.
3. Free of excessive acidity or alkalinity and not high in content of chemicals which precipitate on neutralization or oxidation.
4. Practically free of antiseptic materials and poisonous metals.
5. Low in content of the carbohydrates, sugar, starch, and cellulose.
6. Low in oil and grease content.

With this classification of desirable qualities as a basis it is possible to work out a classification of industrial wastes according to the undesirable characteristics they impart to the sewage. Many wastes have more than one undesirable effect on the quality of the sewage and therefore appear in several of the following classes:

1. Wastes non-uniform in character and discharge: vat dumpings in all industries, particularly the metal and textile industries.
2. Wastes that contain large amounts of suspended matter: wool scouring wastes, beet sugar wastes, unscreened canning wastes, paper mill wastes.
3. Wastes that are strongly acid or alkaline and contain chemicals which produce large amounts of sludge when neutralized or oxidized: steel pickling liquors, mercerizing, kier, bleach and other textile wastes, tannery wastes, paper mill wastes.
4. Antiseptic or poisonous wastes: phenol wastes from coke, gas, and tar industries, metal processing wastes which contain arsenic, copper, zinc, etc., chromium and nickel-plating wastes, paint manufacturing wastes, bleaching wastes, chemical plant wastes, wastes containing soluble sulphides.
5. Wastes which contain carbohydrates (fermenting wastes): milk wastes, vegetable canning wastes, brewery wastes, starch and sugar factory wastes.
6. Wastes which contain oil, grease and soaps: packinghouse wastes, tannery wastes, wool scouring wastes, garage wastes, laundry wastes, silk degumming wastes.

Two additional classifications might be added: one, the group which has high nutrient B.O.D. and thus causes overloading of treatment devices, *e.g.* packinghouse and tannery wastes; and a second group, which includes those wastes that are relatively low in organic solids but large in volume and overload the plant facilities by shortening

detention periods. Condenser and cooling waters and relatively clean wash waters are examples of the latter. Treatment plants should be designed to handle the population equivalent of the high B.O.D. wastes and the clean waters should not be admitted to the sewers.

Control of Variations in Sewage by Regulation of Waste Discharge

Of all the undesirable characteristics of industrial wastes, their intermittent discharge in large volumes and their wide variation in quality are probably the worst. No treatment plant can handle without difficulty a sewage that changes rapidly from strongly acid to strongly alkaline. Where industrial wastes discharges are not controlled, the sewage may in a few minutes change from a highly colored mixture loaded with toxic materials dumped from a textile mill, into a sewage high in carbohydrates from a dumped vat of spoiled milk product.

Equalization of the wastes and regulation of their discharge, is probably the most widely adaptable means for obtaining a sewage-waste mixture of uniform character. Equalization tanks should be so designed that they will not retain sludge. Otherwise the tanks are apt to fill with sludge, lose their effectiveness, and create a nuisance.

Frequently, sufficient uniformity can be obtained if the manufacturer will exert reasonable precaution in regulating waste discharge within the factory. The wider use of automatic flow recorders on waste lines would be of great assistance in studying and controlling irregular waste discharge. When the nature of the troubles caused by dumping wastes is explained to the manufacturer and he is told that unless his waste is discharged in a less detrimental manner, equalizing tanks will be required, he will generally be glad to cooperate.

If the waste is non-toxic, *i.e.*, provides satisfactory food for the bacteria, it should usually be discharged uniformly throughout the 24 hours of the day. However, if the waste is toxic, as is most frequently the case, it must be discharged so that the ratio of waste to domestic sewage will be about constant.

The bacteria and other organisms in a sewage plant have remarkable ability to adapt themselves to adverse conditions and will purify sewage in the presence of considerable toxic material. They cannot, however, adjust themselves to rapidly changing environment. Therefore, to equalize and discharge a toxic waste over 24 hours may result in a night sewage that is as bad for the organisms as the day sewage had been prior to any regulation. Discharge of industrial wastes in proportion to the flow of domestic sewage is the cardinal principal to be followed in attempts to improve plant operation by regulation of industrial wastes.

Although simple regulation of waste discharge always simplifies treatment of sewage-waste mixtures, there are many cases where it does not provide sufficient protection, either because the waste is particularly detrimental or because its volume is large in proportion to the

flow of domestic sewage. In these cases it is necessary to use more complicated methods of control.

Recovery, Reduction, Elimination and Preliminary Treatment

When equalization of waste discharge is not sufficient there are four alternatives: recovery of the waste, reduction of its volume, elimination from the sewers, or preliminary treatment before discharge.

Recovery of by-products should always receive consideration when it becomes necessary to reduce the amount of pollutional material carried in an industrial waste. Although no fixed figures can be given which govern the economics of recovery of the various wastes, there are many examples where recovery has been successful. An enumeration of some of these follows:

1. Recovery of grease from wool scouring wastes.
2. The use of grease, blood and other materials for by-products in the meat packing industry.
3. Recovery of phenols from coke and gas manufacturing wastes.
4. The reuse of white waters in the paper industry.
5. Recovery of milk wastes by evaporation or their use by farmers for feed.
6. The use of caustic mercerizing wastes for preparing keir baths.
7. The preparation of tanning material from sulphite cellulose lyes.
8. Recovery of iron salts from pickling liquors.
9. Recovery of copper from metal processing wastes.
10. Screening of valuable fiber from cloth, cellulose, felt, and paper wastes.
11. Recovery of stock food from starch factory wastes.
12. The manufacture of potash from yeast and distillery wastes.

If recovery is not practical it may be possible to reduce the quantity or the damaging characteristics of the waste by making changes in the manufacturing processes. In some textile mills the use of certain dyes has been abandoned because of the poisonous quality they impart to the wastes. The possibilities for recovery or reduction of wastes within the factory should be investigated by men thoroughly familiar with the particular industry.

The value of recovery and reduction is well established. There is however considerably less certainty concerning the advantage of preliminary treatment as a means of controlling the character of waste discharge. This is especially true when the preliminary treatment involves settling and sludge handling. Preliminary settling tanks at the factory are generally given inadequate attention and the sludge which is removed infrequently often finds its way into the sewers or a nearby stream. Preliminary treatment at the factory should be used only as a last resort unless the installation can be given frequent inspection by someone connected with the municipal sewage department.

Preliminary treatments that have been required in various com-

munities are listed below in accordance with the waste classification given above.

All wastes that contain large amounts of suspended matter may require preliminary settling if the sedimentation and sludge handling facilities at the municipal plant are limited. Wool scouring wastes generally require settling or centrifuging to remove both suspended matter and grease. Beet sugar wastes canning wastes and paper mill wastes, in many cases, may require only screening. Automatically cleaned screens should be used. Preliminary waste screening installations are usually operated satisfactorily, but, as already mentioned, preliminary settling tanks are not always given proper attention. Better results might often be obtained if the money spent on individual treatment plants was used instead to increase the settling and sludge disposal facilities at the municipal plant.

The strongly acid or alkaline wastes, which include pickling liquors, mercerizing, kier and bleach wastes, tannery wastes, and others, may occasionally require neutralization and sedimentation before discharge into the sewers. These wastes offer many possibilities for recovery or reuse in other processes. Frequently the acid and alkaline wastes will neutralize and precipitate one another if combined. Co-precipitation of acid pickling liquors and alkaline tannery wastes are examples. Precipitation of these wastes in municipal plants often overloads sludge digesters, clogs filters, and inhibits bacterial activity.

The antiseptic and poisonous wastes vary widely in their damaging effects. Small amounts of phenol wastes can be handled satisfactorily in biological plants if the per cent of phenol is kept constant. On the other hand, metal processing and plating wastes are very poisonous and should be treated or eliminated from the sewers when biological processes are used. Heiduscha and Gobel have listed the relative effects of various chemicals upon the activated sludge process. Compared to phenol as one, the harmful effects of the others are: cresol 2, sodium sulphide 6.5, sulphurous acid 9.7, caustic soda 20.4, sulphuric acid 167, copper sulphate 218, and chlorine 430. Discharge of the toxic wastes in proportion to the flow of domestic sewage is always important.

The carbohydrate or fermenting wastes are the most detrimental to biological processes of all the common industrial wastes encountered. Milk wastes, alcohol and brewery wastes, starch wastes and vegetable canning wastes are among the worst. Their high oxygen demand and their rapid decomposition with production of organic acids, upset normal biological activity. Digester forming, activated sludge bulking, and filter clogging are the diseases which follow when any considerable amount of these wastes is present in the sewage. Recovery of milk wastes has been mentioned above. Mr. Warrick of the Wisconsin State Board of Health estimates that the maximum permissible quantity of wash water from milk plants is about 20 per cent of the sewage flow, provided waste milk and whey are not admitted to the sewers. At Sparta, Illinois, it was found impossible to treat sew-

age by the activated sludge process when it contained more than 1 per cent casein. Milk wastes produce intense bulking and vile odors when treated by the activated sludge process.

Starch wastes were formerly one of the most objectionable of the organic, oxygen-consuming type, but "bottling up" within the factory, notably at the Argo Plant of the Corn Products Company, and also at other starch plants, has greatly reduced such losses, with recovery of a valuable product.

Screening of canning wastes has been sufficient treatment in some cases while in others preliminary settling or chemical precipitation has been necessary. The fact that some canning wastes are produced for only a few weeks in each year makes their control more difficult.

Wastes containing oil and grease frequently should be given preliminary treatment or removed from the sewers entirely. Wool scouring wastes, tannery wastes, and others should be treated to remove the free grease. Garage wastes should be eliminated. The installation and proper care of adequate grease traps on restaurant and hotel discharge lines will help materially in reducing grease troubles at the sewage plant. Grease, oils, and soaps are expensive and difficult to remove in a municipal disposal plant, form unsightly scum, promote foaming, and interfere with absorption of oxygen in aeration processes. The less grease to reach the disposal works the easier will be the operation at the plant.

Unfortunately, control of the character of the sewage which comes to the municipal treatment plant is often impossible and the operator is compelled to use such emergency or palliative measures as will relieve the numerous troubles caused by industrial wastes.

Operation of Sewage Treatment Plants in the Presence of Uncontrolled Industrial Wastes

Having given considerable time to the control of the first variable, the character of sewage, the last six variable and controllable factors will be discussed briefly in the order listed on page 625.

Controlling Character of the Sewage or Sludge as Introduced into the Various Devices

The two most common methods for improving the character of sewage or sludge are aeration and chemical treatment.

Aeration ahead of settling freshens the sewage, produces a more stable sludge on settling, and aids in loosening and bringing grease to the surface. The aeration is commonly accomplished by placing diffusers in the influent channel. Better equalization, flocculation, and grease removal would be obtained if aeration tanks with some 20 or 30 minutes detention period were provided. In an activated sludge plant this might amount to a type of stage treatment if the excess sludge were returned to the primary aerator.

Chemicals are widely used for controlling the character of the sewage and sludge. Chlorine is used to keep down decomposition and prevent production of hydrogen sulphide. Ferric or ferrous chloride, produced by passing a chlorine solution over scrap iron, has been used for the same purpose and seems to be more economical in some cases. The ferric chloride has the advantage of providing some coagulation.

Iron salts are used at Gastonia, North Carolina, when the color of the sewage indicates the presence of considerable textile wastes. In this plant the sewage goes directly into the activated sludge aeration tanks. Since the intermittent use of chemicals has been started the plant has operated very satisfactorily and color removal has been almost complete.

Addition of lime and other chemicals to regulate the pH of sludge as it goes to the digesters is common practice.

The use of chemicals for control of the distribution of treatment load between the various devices and for controlling the type of organisms and their activity will be mentioned later.

Control of the Temperature of Sludge Digestion

The value of controlled digestion temperature is well understood. As the quantity of industrial waste increases, temperature control becomes more important. Although it is impossible to regulate temperature in the digestion compartment of Imhoff tanks, many difficulties could be avoided by starting new tanks only in the spring or early summer. The warm initial temperature will provide for building up a good quantity of seeding material before the long winter accumulation begins.

Control of Hydrogen-ion Concentration in Biological Processes

Control of pH in sludge digestion has been accomplished by adding lime directly to the contents of the digestion compartment. However, when attempts are made to correct conditions after a tank has foamed the results are often erratic. The best procedure in control of digestion is to learn by experience, or by tests that might be devised, when the sludge going to the tank is of a type that will promote acid digestion and foaming. The character of this sludge should then be corrected by addition of lime or by other treatment, before it goes into the digestion tanks.

Lime has been used in attempts to correct acidity in activated sludge aeration tanks with only indifferent success.

Seeding with Proper Type and Amount of Organisms in Biological Devices

As with the other factors, the control of seeding becomes more important when industrial wastes make the sewage unfavorable for bacterial growth. Withdrawals from sludge digesters should be made

at frequent intervals in order to maintain the proper amount of seeding material and still have available maximum capacity for digestion of fresh solids. Additions of chlorine, lime, or other chemicals are sometimes made to slow down bacterial action or kill off undesirable organisms when digesters foam.

Trickling filter clogging caused by carbohydrate wastes has been controlled with chlorine and ferric chloride. Seeding of trickling filters with humus from other filters that are acclimated to a similar sewage-industrial waste mixture has improved operation of new beds.

The control of seeding or sludge activity in the activated sludge process is so inter-related with the maintenance of a proper oxygen balance that the two factors must be discussed together.

Maintaining Balance Between Oxygen Supply and Oxygen Utilization

In the activated sludge process maintenance of a proper balance between the rate of use of oxygen and the rate at which oxygen is supplied is of importance. The rate of use of oxygen by activated sludge increases with the strength of the sewage and with the amount and activity of the sludge. The rate of use is normally highest when the returned sludge is mixed with the sewage. When a sewage-industrial waste mixture has a high B.O.D. the initial demand for oxygen is frequently in excess of the oxygen supply. When this occurs steps should be taken to increase the oxygen supply or to cut down the rate of use.

The initial oxygen supply may be increased by preliminary aeration. In the absence of separate tanks preliminary aeration can be accomplished by adding the return activated sludge at a point down the tank from the influent end.

If these measures can not be used or fail to supply sufficient oxygen, the demand can be reduced by carrying less sludge in the aeration tanks. Another alternative is to attempt to level off the rate of oxygen usage through the process. One method proposed is to slow down the initial demand with an inhibitive chemical. Chlorine has been used but is so toxic that the regulation of dosage probably is an exceedingly delicate matter. There is reason to believe that occasionally the toxic materials carried in the sewage may automatically level off the rate of use of oxygen through the process. The demand for oxygen might also be made more uniform by the use of tapered return sludge; that is by distributing the return sludge along the first quarter or third of the aeration tanks. It is not known whether this has ever been tried.

Distribution of Treatment Load Between the Various Processes

When plants are heavily loaded with industrial wastes it is frequently possible to improve operation by shifting the burden of purification from one process to another as the occasion demands.

Overloaded secondary processes can be relieved by using chemical precipitants to retain more solids in the sedimentation tanks. This has

proved to be very successful where it does not result in overloading the sludge disposal facilities.

In many plants, however, the greatest difficulties are encountered in operation of the sludge digesters. It may then be advisable to shift a greater portion of the purification load to the secondary processes. The finely divided organic matter which causes trouble in digesters can be sent through the settlers by cutting one or more tanks out of operation and thus decreasing the detention in the remaining tanks.

Summary

Of the seven variables which should be controlled when operating a sewage treatment plant in the presence of industrial wastes, regulating the character of the raw sewage is the most important. Equalization of industrial waste discharge is of great value in obtaining a more uniform and therefore a more satisfactory food for the organisms in a biological plant. Reduction of waste volume, recovery of by-products, or preliminary treatment should be applied in some cases, while in others complete elimination of the waste may be necessary.

When the character of the sewage which comes to the plant can not be regulated the operator must use his ingenuity in treating the sewage or sludge before it is introduced into the various processes and in controlling the temperature, the pH, the seeding, the oxygen balance, and the distribution of treatment load between the various available processes.

Solving the problems of industrial wastes in sewage treatment calls upon the operator for the highest type of service: that of educating all concerned as to the nature of these problems, and of bringing into cooperation the many groups with opposite interests.

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Discussion

By L. L. Hedgepeth

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Mr. Geyer and Mr. Perry have made a long and thorough study of this problem for the Textile Foundation, whose report "Textile Waste Treatment and Recovery" was prepared by them and is well worth a dollar to anyone interested in this problem. The paper presents a comprehensive outline and rounds out a rather ideal picture were it not for the fact that it is predicated on competent and conscientious operation of these pretreatment plants for handling individual wastes at industrial plants.

Mr. Geyer understands the problem and speaks with the clear voice of authority so clearly that I am not prepared to debate his findings on the technical phase of the problem. The control problem assumed in the paper as ideal remains, however, a moot question and in my opinion is the most important current phase of industrial waste disposal.

The importance of operation can not be overlooked if lessening of the shock to the sewage treatment plant from industrial waste discharge is to be converted from an *attainable ideal* to a *realized goal.* Holding tanks are useful but as Mr. Geyer points out the effluent of these tanks must be discharged in proportion to the ability of the sewage to absorb it. Likewise partial treatment of the holding tank

effluent is helpful but here, again, effectiveness is utterly dependent upon competent operation.

This problem seems to be parallel to the relation existing between swimming pool operation and water plant operation, in that the swimming pool treatment problems are not less intense than those encountered in water purification. In fact, they are usually more perplexing. Yet the swimming pool revenues do not usually justify employment of a competent operator who understands the principles of coagulation, filtration, sterilization, algae control, relation of chlorine activity to changing pH, and so on *ad infinitum*. Likewise, the operation of these small industrial waste units often involves perplexing problems, the continual solution of which requires study by a trained observer. Given to the control chemist of the textile plant, the waste treatment plant usually becomes a red headed stepchild and a problem child at that. We *know* that this is the unpleasant fact through chasing complaints that alum won't coagulate, ferric chloride won't dewater, or "we opened the valve on the liquid chlorine tank and gas came out, not liquid—we bought liquid chlorine."

Blind dependence by the operator on coagulants, alkalis, and chlorine, without understanding the interdependence of one on the other and in the proper ratio, is too often false security for the industrialist and problem-creating for the municipal sewage treatment plant receiving the industrial waste treatment plant effluent. I believe we should honestly face this phase of the problem. The industrial plant cannot usually furnish the desired quality of supervision. Supervisory cooperation by the city's sewage technicians is generally not feasible because of suspicion by the industrial managers of any plan which would cede control of their operation to the authority issuing them "cease and desist" orders. They usually prefer to retain actual control of their plants. By the same reasoning, state health authorities are not of much value in supervising daily control of these plants. The equipment manufacturer can not give it, beyond seeing that his equipment is functioning as guaranteed and the chemical manufacturer will not continuously render it because of the small volume of business involved.

A similar condition has existed in the boiler feed water treatment field where industrialists are finding it simpler to purchase proprietary compounds carrying free service than to educate their chemists in the mysteries of boiler water. Thus we find sodium hexametaphosphate, sodium aluminate, sodium sulphate, aluminum sulphate, and various colloidal compounds being sold under proprietary names at fancy prices by consulting engineers and chemists on boiler feed water problems. Their fee is included in the price charged for the chemical commodity. They avoid the stigma of "free" engineering services by asserting that, by going into the boiler feed water treatment plant and giving advice they are defending the good name of their product. A number of competent and ethical consultants have—may I say "stooped"—to this practice. It is abominable. On the other hand, it has proved

workable in the boiler feed water field because the quality of boiler feed water is a most important matter in the economy of the plant's production. The operation of the waste treatment plant of these industrial plants enjoys no such essential relation to its parent and I doubt if such a modified patent medicine practice as is now resorted to in the boiler feed water field, will be feasible in the solution of the control problem in the industrial waste pretreatment plant.

There, seems, therefore, to be a very real need for the treatment consultant—an organization which can and does obtain the industrialist's confidence that his processes and strengths and weaknesses are held inviolate, and which organization will, for a suitable consideration, assume advisory supervision of these plants; an organization which can similarly obtain and retain the confidence of the designing engineer and the municipal and state supervisory authorities.

This, in my opinion, is a pressing need—this problem of industrial waste disposal which we are endeavoring to solve. As in water purification and sewage treatment, it doesn't help much to build plants unless they are operated with a reasonable degree of efficiency.

Mr. C. L. Siebert (*Penna. Department of Health, Harrisburg, Pa.*): In regard to Mr. Geyer's paper, I think there is an increased interest in Pennsylvania in the treatment of industrial wastes because of the recent enactment of a new law relative to stream pollution control. I refer to the passage of a very drastic stream control bill by the General Assembly of the State of Pennsylvania, having specific reference to the discharge of industrial wastes into the waters of the Commonwealth.

I was interested in hearing Mr. Geyer say that considerable difficulty had been experienced in the treatment of activated sludge, particularly where there is a mixture of sanitary sewage and milk wastes. There is a plant in Somerset, Pa., that treats combined sanitary sewage and milk wastes, but the milk wastes are first treated with lime so as to produce calcium lactate, which is removed by sedimentation. There results a 96 per cent purification and a very beautiful effluent.

I would like to ask Mr. Geyer something particularly which relates to statements made in the booklet of the Textile Foundation concerning the mixture of dye waste and textile waste, with sanitary sewage—I don't recall exactly what the assimilable ratio is, but I seem to recall a figure of something like 10 per cent. May I ask if Mr. Geyer has any idea at the present time as to what percentage of its total flow an activated sludge type sewage treatment works should be able to assimilate in the form of typical textile wastes? That is, on the basis of a one-half million gallon plant which would receive about 12,000 gallons per day of a particular hosiery mill's wastes, including soap liquor, dye wastes, and wash water? Does he think that such a sewage treatment works with a half million gallon capacity should be able to assimilate 12,000 gallons of textile wastes per day? I don't say it can or would, but should it be able to do that if properly operated? That is typical hosiery dye wastes amounting to 2.4 per cent of the sewage flow to the activated sewage treatment works.

MR. GEYER: That is difficult to answer, it depends so much upon what the textile wastes are. If it is sulphur dye waste it would be very different than if it is ordinary dye waste. But I should say that it would very easily assimilate it if the wastes weren't discharged all at one certain time, that is, say in an hour during the day. It is almost impossible to answer a question of that kind.

MR. SIEBERT: These vats were discharged at different times during the day, three discharges from each one. So it was scattered throughout the working day. Sulphur dyes were not used. Therefore it would be expected that the load should not be extremely heavy.

MR. GEYER: Well, I would be making a guess. It might handle it all right if it were a well designed plant, and then again they might have trouble with it. I really can't say.

MR. SIEBERT: Is my recollection correct that the booklet of the American Textile Foundation indicates or intimates that 10 per cent has been successfully assimilated and much more may be expected under suitable conditions?

MR. GEYER: I don't believe any definite percentages were given. That would be an extremely dangerous thing to do.

MR. SIEBERT: I thought I did see that in the booklet, but I am not positive about it.

MR. GEYER: It depends entirely upon the plant. However, I think it is possible if the wastes were not discharged suddenly, and if they weren't extremely toxic.

MR. ROBERT W. HAYWOOD, JR: From my experience, I don't believe 10 per cent could be expected, at least with that type of waste, sulphur dye waste that you speak of.

THE EFFECT OF DISTILLERY WASTE ON THE WESTMINSTER SEWAGE TREATMENT PLANT *

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Westminster, the county seat of Carroll County, Maryland, had an estimated population of 4,463 in 1935. Although for a number of years efforts had been made by the Maryland State Department of Health to bring about the installation of a sewerage system, it was not until the establishment of the Federal Emergency Public Works Administration, that these efforts were successful. The engineering firm of J. B. Ferguson, Hagerstown, Maryland, was retained to prepare plans and specifications for a complete sewerage system and sewage treatment works. Ligon and Ligon of Baltimore were the contractors. The total cost of the project, which was completed in the spring of 1935, and included two pumping stations and the treatment works, amounted to $285,020. An outright grant of 30 per cent of the cost was furnished by P.W.A. and the Westminster authorities turned over to the Federal Government bonds for the remainder.

The sewerage system and appurtenant works were designed for an average sewage flow of 750,000 gal. per day, with a maximum daily flow of 2,250,000 gal., based on a population of 5,000, with a daily per capita sewage flow of 150 gal., including infiltration.

The sewage treatment plant consists of a manually cleaned bar screen, primary clarifier, trickling filter, with rotary distributor, secondary clarifier, covered digester, sludge beds, and pump house. A Venturi meter is located between the bar screen and the primary clarifier with the recording mechanism in the pump house.

The primary clarifier is 35 ft. in diameter and 9 ft. deep, with a capacity of 65,000 gal., equivalent to a two-hour detention period. The clarifier is equipped with Hardinge mechanism for sludge and scum removal. The sewage enters at the center and discharges from the clarifier over the outlet weir which completely encircles the tank. A siphon chamber, 21 ft. by 20 ft., with a capacity of 2,600 gal., is located between the primary clarifier and trickling filter.

The trickling filter is 130 ft. in diameter, 8 ft. deep and was designed on the basis of 300,000 gal. per acre ft. of depth. It is equipped with a Simplex rotary distributor.

The filter effluent is discharged into the secondary clarifier which is 28 ft. in diameter and 7 ft. deep. This unit has a capacity of 32,500 gal., equivalent to a one-hour detention period. It is equipped with a Hardinge mechanism for sludge removal. The effluent of the clarifier discharges into the stream without further treatment.

The sludge digestion tank is 35 ft. in diameter and 16 ft. deep and has an effective sludge capacity of 1.5 cu. ft. per capita. The digester

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is covered but the gas is not utilized, being discharged into the atmosphere from the top of a flagpole. Heating coils were installed for future use, should heating of the sludge become necessary. Hardinge mechanism is installed for breaking up the scum and also for moving the sludge along the bottom of the digester. The sludge discharges by gravity to four open sludge beds which have a total area of 0.80 sq. ft. per capita.

FIG. 1.—Westminster Treatment Works. Pumphouse and secondary clarifier, with sludge beds in background.

FIG. 2.—Westminster Treatment Works. Trickling filter with primary clarifier and covered digester in background.

The sewage plant was placed in operation in the spring of 1935 and for about a year functioned in a very satisfactory manner. In April, 1936, however, its operation was suddenly upset by the discharge of distillery waste into the sewerage system. The State Department of Health was notified that difficulty was being encountered and the writer

was assigned to make an investigation and advise the authorities as to the proper procedure for overcoming the difficulties in plant operation.

It was found that the digester was foaming, causing an excessive amount of solids to overflow into the primary clarifier, which produced septic action therein, with consequent boiling over of solids on to the trickling filter. There was a frothy scum on the surface of both the primary and secondary clarifiers, with a large amount of solids being discharged into the stream. The pH of the sludge in the digester was below 4.4, the lowest range carried by the writer.

One day, while checking over the operation of the plant, samples of the normal raw sewage were collected for laboratory analysis. About an hour later, a full charge of distillery waste was noted in the raw sewage and another sample was collected. The analyses of the two samples are tabulated below:

	Normal Raw Sewage	Raw Sewage Containing Distillery Waste
Total solids	—	9144 p.p.m.
Suspended solids	224 p.p.m.	3190 p.p.m.
Settleable solids	158 p.p.m.	2892 p.p.m.
Volatile solids	—	8358 p.p.m.
pH	6.8	4.0
B.O.D.	264 p.p.m.	3875 p.p.m.

It is interesting to review the following tabulation, which indicates the efficiency of the plant during this period, in comparison with normal operation. The figures in the tabulation are averages calculated from analyses of samples collected during normal operation and from those collected during the time the sewage was carrying distillery waste.

	Raw Sewage		Plant Effluent		Per Cent Removal	
	Normal	With Waste	Normal	With Waste	Normal	With Waste
	(Average)		(Average)			
Suspended solids	234	2090	33	260	85.9	83.5
Settleable solids	152	1768	18	166	86.8	90.6
B.O.D.	295	1925	34	350	88.5	81.7

Results in parts per million.

It will be noted that the plant continued to function with about the same percentage efficiency even when carrying the distillery waste. Although the percentage of removal of solids was about normal, the resultant effluent was higher in solids and B.O.D. than the normal raw sewage and could not be discharged into the receiving stream for any length of time without causing a serious nuisance.

At this time the average daily sewage flow was approximately 350,000 gallons. About 3,500 gal. of distillery waste was discharged

into the system twice a day, each discharge lasting about 40 minutes. The first step to correct this condition was taken when a conference was held between the city authorities, the distillery officials and representatives of the Bureau of Sanitary Engineering of the State Department of Health. At this meeting, it was agreed that no more distillery waste would be emptied into the sewerage system except in emergencies, at which time the waste should be diluted with 100 parts of water to 1 part of waste and the discharge to be spread out over a longer period. The city authorities were to be advised before any such discharge took place.

At the same time, an effort was made to bring back satisfactory conditions in the digester. Lime was added to raise the pH and the sludge was recirculated to stop foaming. It appeared as though this treatment was to be successful, when about the first of July, without warning, the distillery again discharged waste into the sewers for a period of two days and in the same concentrated doses which had previously obtained. This not only retarded the progress being made in restoring the digester to proper functioning, but seemed to greatly aggravate the foaming condition. More lime was added and recirculation of the sludge continued. The mechanism in the digester was operated a few hours a day, also continuously, but no improvement was indicated whether the mechanism was operating or not. Continuous recirculation, however, kept down foaming and prevented some of the solids from going over into the raw sewage. Even though sufficient lime was added to bring the pH of the sludge to 7.2, the foaming continued until chlorine was added to the digester. It was noted that this materially affected the foaming condition and after 22.5 pounds of HTH were added, or approximately 16 pounds of chlorine, all foaming stopped.

The digester was functioning satisfactorily on October 2, 1936, after having been in an upset condition since April 18. During this period sludge was drawn as fast as it could be dried and removed from the sludge beds in order to keep down the foaming. Due to the high solids in the sewage reaching the trickling filter, this unit was sloughing practically the entire time.

Shortly after the trouble was encountered at the plant, it was recommended to the city authorities that the plant operator be supplied with Imhoff cones and pH testing equipment, so that the operation could be more readily followed and controlled. This equipment was obtained and weekly reports of daily tests are now submitted to the Bureau of Sanitary Engineering, so that any unusual operating conditions can be readily noted. When necessary, corrective measures are taken to prevent a recurrence of the above difficulty.

THE DISPOSAL OF SLUDGE AND GAS—BY-PRODUCTS OF SEWAGE TREATMENT *

By L. S. Kraus

Chemist, Peoria Sanitary District

The treatment of sewage solids by digestion in Imhoff tanks or in heated digesters produces a residual digested sludge containing a relatively low nitrogen and phosphorous content and a gas consisting chiefly of methane and carbon dioxide. With the disposal of these materials the task of sewage treatment is completed.

The disposition of the gas is simple, complete, and in many cases remunerative. It may be wasted to the air with or without burning, depending on its volume and the hydrogen sulphide content; it may be used as a fuel in boilers for heating digestion tanks and buildings; and it may be used in gas engines for the production of power.

The gas when wasted to the atmosphere has no value and in some cases where burning is necessary involves a small cost to the plant. When used as a source of fuel for boilers a 650 gross B.T.U./cu. ft. gas is worth about eight cents per thousand cubic feet. This is based on a $2.50 per ton, 10,000 B.T.U./lb. coal.

Gas used as a source of power is the most remunerative practice. In addition to the value of power produced, about 55 per cent of the total heat in the gas can be reclaimed as hot water from the engine water jackets and exhaust gas. If all of this heat can be utilized, 1,000 cubic feet of the above gas has a value of about thirty cents on the basis of power and fuel costs, and engine operation at Peoria. If the heat can not be used the gas has a value of about twenty-six cents per 1,000 cubic feet.

The disposition of digested sludge is a far more complex problem. It can be used as fill, or burned and the ash used as fill, or it can be used as a fertilizer, either as it is removed from drying beds at about 50 per cent moisture or as a dried product at 5 to 10 per cent moisture.

Digested sludge does not make a good material for fill. It does not compact sufficiently to make a firm non-resilient material. The ash resulting from sludge incineration will make a fair fill; however, the cost of incineration is sufficiently high to make this procedure of little use in small plants. The use of sludge as a fertilizer, however, is widely practiced.

Digested sludge, as it is removed from the drying beds, is classed as a low grade fertilizer containing small amounts of nitrogen and phosphorous, little if any potassium, and large amounts of organic material nebulously referred to as humus and moisture.

The U. S. Department of Agriculture in Bulletin No. 1280 cites the following advantages of low grade fertilizers over the higher grade chemical fertilizers:

* Presented Before the Fourteenth Annual Meeting of the Illinois Association of Sanitary Districts, Waukegan, Ill., June 17, 1937.

1. A market for industrial by-products which would not otherwise have a market.

2. Fertilizing constituents may vary greatly in availability and thus serve to supply food to the plant throughout the growing season.

3. While many constituents such as sulphur and different forms of organic matter add nothing to the commercial value of fertilizer, they may nevertheless have a beneficial effect on the soil.

4. Many low grade materials have properties which improve the physical condition of the soil.

5. Small amounts of fertilization can be applied more conveniently in the form of a low grade fertilizer than in the form of high grade materials.

Sewage sludge has all of these advantages, particularly those of delayed availability of its nitrogen and soil conditioning.

At the 1935 meeting of this Society, Professor DeTurk pointed out that the chief objections to the use of digested sewage sludge as a fertilizer were the low percentage of available nitrogen present and the large cost of transportation.

Digested sludge may be used as a fertilizer as it is removed from the drying beds, either by placing it in a stock pile and loading into trucks during the period of demand, or by allowing the users to remove it from the beds. The latter practice is not practicable in the larger plants but is quite feasible in the smaller ones. By these methods the user gets a sludge that may run from 35 to 60 per cent moisture. At Peoria, since the demand for sludge is in the early spring and the late fall, the farmer usually receives it with a moisture content of 50 to 60 per cent. Except for the sludge that has frozen during the winter months the material is lumpy and not especially suited for distribution in the field.

The most satisfactory physical condition for the sludge from the users' standpoint is when it is dried to from 5 to 10 per cent moisture content and ground to less than six-mesh particles. The production of such a product involves a considerable capital expenditure for a drying and milling plant, and as estimated for Peoria, would result in a cost of from \$4 to \$5 per ton of finished product. This cost is in addition to the cost of \$1 per ton for removing sludge from the drying beds. At present the value of this product as estimated from its nitrogen and phosphorous content and current market values for these materials is about \$6 to \$7 per ton delivered to fertilizer mixers. This allows about \$2 per ton for the cost of delivering the material after the cost of processing is deducted. The freight rate from Peoria to Chicago is \$2.60 per ton in car load lots. It is apparent that the cost of production plus freight to market, assuming, of course, that there is a market, is not sufficient to hazard the undertaking, even as a non-profit venture.

In an attempt to determine the amount that can be paid for sludge in the stock pile I have worked out the following analysis with the aid

of Mr. Joseph B. Schoff, one of the enterprising truck farmers in our area.

This farmer is located three miles from our treatment plant. We give the fertilizer away, the farmer loading from our stock pile to trucks and hauling it to his field for distribution. It costs him about 17 cents per cubic yard or 60 cents per ton of dry solids to haul and spread the material on his field.

The area under consideration is fertilized in the late fall to the extent of fifteen tons of dry solids per acre at a cost of $9 per acre. The sludge is left on top of the ground over the winter and in February spinach is sown broadcast and the ground lightly harrowed. The spinach crop is cut late in May and the ground is plowed about eight inches deep and planted in tomatoes. The tomato crop is harvested and the ground plowed again about the middle of September, spinach being again planted in the area. The fall spinach crop is collected and the area is plowed and fertilized late in fall for use the following year. A one acre unfertilized control area adjacent to the above tract was planted with the same crops.

The above procedure has been carried out for three successive years. Each year the yield of spring spinach in the fertilized area has exceeded the yield in the unfertilized area. No appreciable difference has been observed in the tomato and fall spinach crop in the two areas. The tomato crops have been very poor in both areas due to the lack of water in the past two years. At the present time the tomato crop in the fertilized area is far ahead of that in the unfertilized area. The following analysis is an average of three spring spinach crops, yields being based on spinach sold.

The fertilized area yielded 343 bushels of spinach per acre and because it matured about seven days earlier than most other spinach around Peoria, was sold at 53 cents per bushel, about 13 cents per bushel more than the average price. The control area yielded 241 bushels of spinach per acre and was sold for 40 cents per bushel. Thus the fertilized area yielded 102 more bushels per acre than the unfertilized area which resulted in a gross increase in income of $85.39 per acre. The net increase in income after deducting the cost of fertilizer and cutting and packing of the 102 bushels of spinach, was $66.19. This is equivalent to $4.41 net yield to the farmer per ton of dry solids of fertilizer applied and $1.24 per cubic yard of fertilizer as received.

From this analysis it pays Mr. Schoff real dividends to use our sludge. If all of the farmers in our vicinity had equal success with the sludge it appears that a charge of 25 cents to 40 cents per cubic yard would be reasonable. It is obvious from the analysis that spending $4 to $5 per ton for drying the sludge is quite out of the picture since the farmer realized but $4.41 per ton of dry solids used.

At Peoria we produced about 13,000 cubic yards of sludge or 3,600 tons of dried solids during 1936. We have given away all of our sludge except about 2,000 cubic yards. During 1936 we have had some competition from a stockyard's manure which is not only free of cost

to the farmer but in addition is loaded on his truck. Many of the farmers prefer this material to our sludge for such products as cucumbers, sweet potatoes and radishes.

Practically all of the sludge is used by farmers, a small amount, however, being used for lawn and golf course areas. To date we have given away about 52,000 cubic yards of this material, most of the farmers hauling from 100 to 500 cubic yards per year, for an average distance of fifteen miles.

Reports on Other Treatment Plants

At Aurora, Superintendent Sperry reports a production of about 2,000 cubic yards of dried sludge per year, a small amount of it being used on golf links, local lawns and farms. The sludge is piling up at present and an effort is being made to interest farmers and a local fertilizer company in the use of the material.

At Galesburg, Chemist Hunt reports a yield of 800 cubic yards of dried sludge per year, some of which has been used on local lawns, gardens and farms.

Superintendent Henn at DeKalb reports a production of 200 cubic yards per year. It is used largely around the plant and by local residents for lawns, and at present the demand is such that tentative orders for 100 cubic yards at 50 cents per cubic yard have been placed.

Dr. Hatfield at Decatur reports that between 3,000 and 8,000 cubic yards have been removed from the drying beds by his personnel during the past several years, small amounts of which are used by farmers and country clubs. The sludge is piling up at present. Tests in clay sub-soil indicate remarkable yields on white icicle radishes, beets, cabbage, beans, and swiss chard.

W. H. Rogers at Downers Grove produces 500 cubic yards of dried sludge per year, most of which is used for local lawns. Some of the sludge is sold for $1 per load delivered, and the demand is such that orders for delivery in the spring of 1938 have been placed.

Superintendent Smith at Elgin reports an average production of 1,178 cubic yards, most of which is used for fill around the plant.

Chemist Larson at Springfield reports that about 1,000 tons of dried sludge at 50 per cent moisture content is produced yearly. It is given away to parks and small farmers and used on lawns and shrubs around the plant.

At Wheaton Mr. O. C. Gellinger reports a yearly production of 75 to 100 cubic yards, all of which is removed from the beds and used by local florists.

SLUDGE DISPOSAL AT THE CHICAGO WEST SIDE WORKS *

DISCUSSION OF PAPER BY L. S. KRAUS

By C. V. Erickson

Formerly Asst. Civ. Eng., Sanitary District of Chicago; Now Supt., Urbana-Champaign Sanitary District

As this paper is intended to deal primarily with the final disposal of sludge at the West Side Treatment Works of the Sanitary District of Chicago, only passing mention will be made of the method of handling the wet sludge.

Briefly, after being drawn by gravity from the Imhoff tanks, the sludge is discharged by pneumatic ejectors through a 24 in. line to the drying beds. The beds provide a total drying surface of 27.3 acres, consisting of thirteen beds ranging in length from 800 to 1400 ft. Each bed is 80 ft. wide with rails on the sidewalls to carry the sludge stripping machines. The beds are in pairs with a standard gauge railroad track between pairs. The two cleaning machines, gasoline-electric driven, strip the sludge and convey it into dump cars of 30 cu. yd. capacity spotted on the adjacent track.

Final disposal of most of the sludge consists of hauling trains of filled cars, by means of an oil-fired locomotive, to the dumping area about 3 miles west of the plant. This low area, District owned property, is an old bed of Des Plaines River north of the Main Channel. Originally we used two 1200 ft. wooden dumping trestles located in this area. As the sludge piled up along these trestles to a height which interfered with further dumping, a drag line was placed in use for a period of several days to cast the sludge away from the trestles into the wide area between them.

Recently, however, these trestles were abandoned, the timbers salvaged, and the rails utilized for a new dumping track located on an existing clay spoil bank along the north bank of the Main Channel. We dump to one side only of this embankment, the sludge sliding down into the extensive low area to the north. It is expected that this improvement will effect an appreciable economy by the elimination of extensive maintenance of the wooden trestles, and a reduction in rehandling of dumped sludge.

Throughout the drying season we keep several cars of dried sludge spotted in a place convenient for loading into trucks. No charge is made for sludge taken away. In addition to this we dump cars on an area near a macadam road in the plant for the convenience of people who drive in with small trailers or who merely wish to load a few sacks or baskets. Last year an attempt was made to accommodate a large user of sludge by loading trucks direct from the bed cleaning machines

* Presented Before the Fourteenth Annual Meeting of the Illinois Association of Sanitary Districts, Waukegan, Ill., June 17, 1937.

but the wear and tear on the track system and our adjacent lawns soon demonstrated the folly of this procedure. From time to time relatively large amounts of sludge have been shipped in railroad company cars contracted for by the consumer, for use in orchards located in Michigan. Rail shipments have also been made in our own cars to our North Side Plant for use in landscaping work. A W.P.A. landscaping project in progress at the West Side Plant has utilized a considerable amount of sludge for both lawns and shrubbery.

Additional users of sludge have been golf courses, W.P.A. landscaping projects in Chicago and the suburbs, nurseries, farmers, owners of relatively large estates, such as one who trucked many loads out near Woodstock, and private home owners.

One interesting angle on this utilization of sludge is the setting up of an experiment by the District to determine whether a top soil suitable for the growth of grass and shrubbery can be created by the right mixture of clay and dried sludge. Plenty of clay is available in spoil banks so the success of this idea would simplify the problem of eventual landscaping around the new Southwest Treatment Works.

At this point it might be well to present a few figures for the years 1932 to 1936 inclusive on quantities and analyses of the sludge:

Year	Sludge Drawn From Imhoff Tanks		Sludge Removed From Drying Beds				Aver. Thickness, Inches
	Cu. Yd.	Per Cent Moist.	Cu. Yd.	Per Cent Moist.	Per Cent Vol.	Per Cent Nitr.	
1932	216,000	94.4	40,300	38.8	44.4	2.24	3.8
1933	288,000	94.1	43,700	46.5	46.2	2.37	3.6
1934	286,000	94.1	36,500	41.0	45.5	2.18	3.1
1935	217,000	92.7	36,800	47.2	43.5	2.06	3.3
1936	193,000	91.9	36,200	42.0	41.8	1.96	3.1

The progressive decrease in nitrogen content is due to the additional raw sewage treated as more city sewers were connected to the interceptor, thereby increasing the ratio of fresh solids to North Side waste activated solids.

Sludge is dosed on the beds to a depth of about ten inches. Late in the fall, usually during the latter part of October and the early part of November, the drying season is brought to completion by dosing all the beds, leaving the Imhoff tanks with sufficient seeding sludge and the necessary digestion capacity for the accumulation of solids until April. Early in April the sludge which has been on the beds all winter is stripped off and the beds re-dosed immediately. This winter sludge is, of course, entirely different in texture from summer dried sludge but presents no serious problem of removal with our machines. The primary reason for dosing our beds in the late fall was, at the outset of operation, to prevent drifting of the sand on the beds.

Control data utilized in the sludge handling operations include

monthly sampling of the sludge at 3-foot intervals in six individual tanks in each battery of Imhoff tanks. From these data a weighted average per cent moisture and per cent volatile content is computed for each tank sampled and for each battery. These samples are obtained with a pitcher pump and a 1½ inch suction hose. The lowest samples collected are from a point 4 ft. above the bottom of the digestion compartment.

During the drying season, sludge levels in each of 108 Imhoff tanks are determined about every three weeks, and about every month during the winter. This information is used in determining the amount of sludge to be drawn from individual tanks and the sequence of tanks to be drawn from each day. Levels are determined by means of a pitcher pump and a 1¼ inch suction hose lowered through the gas vents.

Reverting to the utilization of dried sludge, it may be of interest to present a summary of cars handled in 1936. About 60 per cent of the total of nearly 1200 cars loaded were taken to the dump. Distribution of the other 40 per cent or 480 cars was as follows:

Rail shipments to Michigan orchards	35 cars
Trucked to Municipal Tuberculosis Sanitarium grounds	8 cars
Trucked to a nursery	7 cars
Spotted on track in plant for convenience of larger trucks	150 cars
Dumped in plant near road for use on West Side landscaping and for convenience of small users	280 cars

Of the last mentioned 280 cars a little less than half the quantity has been hauled away to date. Thus a total usage to date of about 25 per cent of last year's sludge is indicated.

Many trucks find it more convenient to haul from the dump, but no attempt has been made to keep a record of those removals because of its remoteness from the plant and the fact that there is ample room for dumping for many years in the future.

DISCUSSION OF PROFESSOR MALCOLM'S PAPER*

"STUDIES IN THE DIGESTION OF GROUND GARBAGE"†

By Morris M. Cohn

Sanitary Engineer, City of Schenectady, N. Y.
Editor, "Municipal Sanitation"

Professor Malcolm's investigation of the digestibility of ground garbage adds another chapter to the story of the sanitary engineers' recent interest in garbage and its behavior when mixed with sewage, a material which we have been studying for a longer time and about which we have been learning many interesting things. In writing this new chapter, the Cornell studies are of great importance to us since (1) they add further confirmation of the digestibility of sewage-garbage mixtures and (2) they prove in a practical manner the similarity of sewage and garbage, the two putrefactive organic wastes of community life.

We owe Professor Malcolm and his associates a vote of gratitude. May I, as Chairman of the Sub-Committee on Sewage and Garbage Disposal of the New York Association Research Committee, publicly thank Professor Malcolm for his untiring, patient investigation. Much credit is due the laboratory worker. Investigation of plant-scale reactions provide easily recognized stimulation but the only stimulation offered by playing wet-nurse to a battery of barrels is the scientist's desire to learn the truth. Much has been said about the greater significance of plant-scale studies in the sanitation field. May I say that much progress has had its source in laboratory-scale studies of the caliber demonstrated by Professor Malcolm.

If there were further need to demonstrate the ability of garbage to digest in the presence of raw sewage and digested sludge solids, these present studies have provided this proof. Fair at Harvard, Keefer and Kratz at Baltimore, Calvert, Bloodgood and Tolman at Indianapolis, Babbitt at the University of Illinois, Carpenter and Grabois at N. Y. U., Rudolfs and Heukelekian at the New Jersey Sewage Experiment Station and the writer at Schenectady have all demonstrated, more or less specifically, that mixtures of sewage and garbage are digestible into a normal sludge. Tests at the Lawrence Experiment Station recently reported by Chief Engineer Weston of the Massachusetts State Health Department show the ability of Imhoff tanks and septic tanks to function normally with garbage. It is significant that a decade of study is already behind us.

Professor Malcolm has added new proof that sewage has no sole option on the anaerobic processes that convert organic materials into unobjectionable, disposable material. In doing so, he has added proof of the feasibility of the combined handling of sewage and garbage.

* Presented at the Spring Meeting of the New York State Sewage Works Association, Utica, N. Y., June 3, 4 and 5, 1937.

† See *This Journal*, Vol. 9, P. 389, May, 1937.

There has been much doubt and equal confusion among investigators over the proportions of sewage and garbage that are digestible; equal doubt has been raised over the safe rate of application of such mixtures to seeding sludge. The practical significance of these questions is self-evident, since the answers either prove or disprove the ability of the sewage treatment process to handle another phase of sanitation practice. The great stress placed upon digestion studies is readily understandable; if garbage is not digestible, it should not be permitted entrance into the sewer system under any consideration.

As a result of indefinite engineering opinion on the conditions which would be imposed upon a treatment plant if garbage were added to sewage, unfortunate variation in basic factors of investigations have resulted. No two investigators have agreed on the normal proportions of sewage and garbage produced by a community, on the true composition of garbage or on the expected rate of application of resulting sewage-garbage mixtures into digestion tanks. Proportions of sewage to garbage have varied from less than 1:1 to more than 1:2½. Similarly, rates of application to digested sludge have carried from 2 to over 5 per cent. Again, temperatures of digestion have varied over a wide range. Professor Malcolm has chosen daily additions of sewage-garbage in proportions of 1:1, 1:1½ and 1:2 and he has added this mixture in amounts to digestion tanks which truly correspond to Ithaca sewage plant practice.

The time is not propitious here to argue for or against any of the test conditions established by any of the investigators of this important phase of sanitation. That I believe that a normal community will produce proportions of volatile sewage solids and volatile garbage solids that will seldom be more than 1:1.3, is merely my opinion. I am more interested today in the broader aspects of the problem.

Engineers have held tenaciously to old concepts. They have reasoned that since garbage is different from sewage it is impossible that it should function as sewage does in the digestion process. Having been shown that this material does digest, the next natural reaction is "it may digest, but only a limited amount will do so." With sewage we are well acquainted, with garbage less so. This reluctance to accept generalizations has led to the various researches to which I have referred.

If we consider our problem as an unknown curve, every varying opinion has produced experimental conditions which have added more points to the empirical curve. Bit by bit, we have developed a curve which begins to demonstrate that sewage-garbage mixtures are digestible in those proportions which will be produced by average community life. Professor Malcolm's studies trace new portions of this curve.

There is, however, a greater truth demonstrated by the Cornell studies. It is the ability of garbage alone to digest equally as well in the presence of digested sludge as sewage alone or as mixtures of sewage and garbage. By all of the known measuring sticks, Professor

Malcolm has demonstrated strikingly the ability of daily additions of properly pulped garbage to digest into a satisfactory sludge.

What does all this mean? Since garbage acts like sewage, it must be the same material. This to me is a striking practical demonstration of a statement I made just three years ago before the Oneonta meeting of this Association. At that time, I attempted to point out, in a homely manner, that sewage and garbage are alike. Professor Malcolm's Tanks 2 and 3 have brought home this truth, perhaps better than my presentation could have done.

Those of us who have long dealt with sewage have given to it definiteness of character which it does not possess. The less uninitiated see in sewage a heterogeneous mixture which contains large quantities of food wastes of the same composition as garbage. The average American consumes over a ton of food per year, much of which becomes normal constituents of domestic sewage. Who can say what proportion becomes sewage of the 62 lb. of beef, 12 lb. of coffee, 102 lb. sugar, 177 lb. of flour, 17 lb. of butter, 167 lb. of fruit, 18 dozen of eggs, 180 lb. of potatoes and 918 lb. of milk which constitutes the diet of those of us who do not fear for our waistline. It might appear that we are put in a position of daily doing something which we have recently taken the pains to investigate scientifically. We have been treating garbage for years but we haven't called it garbage, we have called it sewage. Grind it, introduce it into the sewer and I defy anyone to separate it and say *this* material is *sewage* and *this* material is *garbage*.

Three years ago, a college professor said to me, "Cohn, combined digestion of sewage and garbage looks like dangerous procedure to me. It would never work in our college community because of the high grease content of the food waste. You know, grease does not digest and it would produce scum blankets in digesters which would be impossible to handle." These fears have proven to be unfounded. Such investigators as Bloodgood have definitely stated that garbage hastens digestion rates and that the presence of grease apparently acts as a catalyzer. Now we have tests on college town garbage which show no delay in digestion, no impairment of sludge gas and no scum troubles. May I close with the philosophical warning "Never say it can't be done. While you are saying it, someone is doing it."

DISCUSSION

By Willem Rudolfs

Chief, Division of Water and Sewage Research, Agricultural Experiment Station, New Brunswick, N. J.

At present the amount of garbage received at a sewage treatment plant depends upon the efficiency of the garbage collection system. At some treatment works comparatively large quantities of garbage have been received for years. When fine screens are present a portion of the garbage is removed from the sewage and is either disposed of

or broken up and returned to the sewage. As long as the amount of garbage (screenings) does not exceed 10 to 15 per cent of the total suspended solids, no particular attention is paid to the digestion of the mixtures, except at places where the digestion capacity is insufficient. *A priori*, there is no reason to believe that, with proper seeding and control, any amount of ground garbage added to the sewage should digest differently than sewage solids. Experiments made years ago in the laboratory and on a plant scale (Milwaukee) to digest screenings (garbage) as received without sewage sludge, have shown that digestion is feasible and that a gas with comparatively low methane content is produced. The quantity of gas produced from such screenings is rather low, amounting on a plant scale to 5.7 cu. ft. per pound of dry solids (*This Journal*, **1**, 519 (1930)). When the loadings are reduced, or the digestion time increased, the quantities of gas produced increase, indicating that the material is probably somewhat more resistant than sewage solids.

In the Ithaca experiments the garbage did not contain raw vegetable tops or cuttings but in addition to meats and bread, cooked and uncooked vegetables, fruits, etc. which were left on the plates were present. It could be expected that this garbage would digest somewhat better and more rapidly than if all waste, including potato peelings and other vegetable debris, had been included.

From the paper it is not quite clear whether all wash water (supernatant liquor) produced by grinding was added to the digesting mixtures. The soluble substances present in the wash water decompose rapidly and have a tendency to make the mixtures acid. If the wash water has been added, a partial explanation for the earlier acidic conditions in the tanks receiving garbage alone may be found. Another possibility is that, during the earlier stages, ammonium carbonate production from the garbage mixtures was slower on account of a wider carbon-nitrogen ratio than in the sludge. After some time, especially with the aid of some reaction control, decomposition of nitrogenous material would be speeded up, resulting in a gradual correction.

Under ordinary conditions of grinding garbage, either in the home or at a central place, the soluble substances would pass through a settling tank. Such garbage sludge would produce less difficulties in the digestor, although in the earlier stages an increase in acidity could be expected on account of decomposition of the disintegrated carbonaceous particles.

Of considerable interest is the fact that the methane content of the gas produced was rather low, with the presence of more than the usual hydrogen content. It is a well known fact that during the earlier stages of digestion, gas production is relatively low with rather high CO_2 and H_2 contents. In this respect it should be kept in mind that the digestion temperature was considerable below the optimum for mesophilic digestion. The comparatively low gas production, rather high hydrogen content and low temperature would seem to indicate that at no time was complete digestion obtained.

The differences in composition of the mixtures to which garbage was added were not large enough to show marked variations. A comparison between sludge alone and garbage alone, with the garbage-sludge mixtures in between, shows clearly that under the conditions of the experiment there was no unusual difficulty to digest the materials.

It is rather difficult, if not impossible, to show a proper solids balance. The results under discussion are no exception. The difficulty is not so much with the standard technique as with the standard method. With the method used a certain amount of the volatile matter, sometimes amounting to as much as 20 per cent or more, is driven off on drying. On account of decomposition, more volatile substances are lost. As a rule the further digestion has progressed the smaller the differences between the ripe sludge and original material, because the volatile material has been changed to gases. Other methods for determining the volatile matter of sewage solids are either too complicated and cumbersome for routine work or have different inherent faults, producing results not much better than the method generally used.

In conjunction with other work on garbage-sludge digestion published recently, the Ithaca experiments show that garbage added continously is not detrimental, but that the digestion capacity required increases in direct proportion to the quantity of volatile matter. The amounts of volatile matter added daily were lowest with garbage alone and in between when a mixture of garbage and fresh solids was added. Since none of the results indicate a more rapid digestion of the garbage or garbage-fresh solids mixtures, and no more total gas was produced from these mixtures than from the control, it may be assumed that under the conditions each pound of volatile garbage solids required the same digestion time as each pound of volatile material in the fresh solids. Consequently, when 100 per cent garbage is added (on the basis of fresh solids) the digestion tanks must be at least twice as large.

Early plant scale experiments with digestion of screenings showed that a considerable portion of the material had a tendency to float and was difficult to keep submerged. The screenings were added from the top. Later results showed that it was essential to mix the screenings thoroughly with the digesting sludge to prevent excessive scum formation. Laboratory experiments on garbage-sludge digestion showed that the manner of adding the ground garbage was important to prevent floating material. The suggestion made by the author that adding sludge and garbage near the bottom of the tank may in part account for the absence of scum, has merit, but it should be kept in mind that there is no indication to show that the tanks were worked to capacity. The gas production curves seem to show that the rate of gas production was fairly constant for all mixtures. As soon as tanks are worked to capacity or somewhat overloaded, difficulties such as foaming and scum formation are more likely to appear.

It would have been of considerable interest if experiments had been

made concerning the dewatering or drying of the different sludges. Such results would have been a good check on the degree and extent of digestion of the mixtures. Does ripe sludge obtained from garbage-fresh solids mixtures dewater and dry as well or better than well digested ripe sludge obtained from sewage solids? Would possible odor nuisance be increased or reduced?

In conclusion, the discusser wishes to congratulate the author for the work done. Only those who are familiar with this type of experimentation can perhaps fully appreciate the large amount of work necessary to make the presentation of such a paper possible.

General Discussion

Mr. C. A. Emerson.—Doctor Rudolfs points out that garbage used at Cornell was residue from the plates and not necessarily the same kind of garbage that would come from the entire preparation of food used in the household. This may or may not be important. However, it should not be overlooked. The digestion of garbage and sewage together is a point which is vital. Other things must not be overlooked if garbage is to be added to municipal sewage. Regarding sedimentation, will the efficiency of the tanks for removal of suspended solids be decreased or increased? Will it increase the load of solids? Will the effect on removal be changed?

Garbage from municipalities contains a great deal of grease; scum removal may be a great problem. Will it be in proportion, if grease is not skimmed, to about the same percentage we now have? Are we going to increase nozzle clogging? What will the effect be on the activated sludge plant? We are facing a tremendous problem which affects every angle of sewage treatment. It goes far beyond the question of whether or not garbage and sewage sludge can be digested.

Mr. M. M. Cohn.—May I ask what exact composition of garbage was used? What were the materials? Garbage is produced either by preparation of meals or by cleaning up after meals. Were materials used from preparation of meals? Were there no potato peels?

Professor Malcolm.—There were no potato peelings or raw green tops, except carrot tops. There were, on occasions, nothing but rinds from muskmelons, watermelons, onions, and raw fruit, left on plates. On some days there were nothing but corn cobs. It was in part cooked food and in part raw food.

There were two points brought out by Doctor Rudolfs. He asked if anything was washed out of garbage as we took it. The answer is no. Garbage was put through a grinder and all garbage, including water used to grind it, was garbage and all went into digestion. There was no animal compound or protein washed out. It was garbage *in toto.*

Second, in regard to drying of sludge. Mr. Spry made experiments, and in order to lighten myself of the load in carrying out sludge, I gave him all the sludge. He used it in comparison with Ithaca sludge

and raw sludge and found that digested garbage and sewage sludge from my tanks drained a little bit better than digested sludge. I hope that some day he will put these facts on paper. There was slightly better drainage of the mixed garbage and sewage than there was of sludge. Draining was made on sand beds under standard glass covers, *i.e.*, normal conditions of sludge draining on covered beds.

Mr. L. H. Enslow.—Composition of the gas generated would give some indication as to what you might expect, *i.e.*, the quantity and quality of the gas.

Professor Malcolm.—Gases which were given off analyzed about 26 per cent CO_2. Normally I find in sewage gas from Ithaca that the CO_2 content runs somewhat over 30 per cent. The CH_4 content was found to vary from 74 to 75 per cent, or perhaps higher, to as low as 40 per cent. This was found to happen in the course of tests at the Hamilton, Newark, and Ithaca sewage treatment plants.

The digester CO_2 was lower than Ithaca, by about 4 per cent. CH_4 is very variable. Hydrogen varied from 17 per cent to practically nothing. That would represent analysis of gas coming from a tank. We found a great deal of variation, particularly in relative CH_4 content and H_2 content.

L. H. Enslow.—Progress is being made on operating gas information in sewage treatment plants. It may be that trying to digest garbage with sludge may have a very deleterious effect on the uniformity of gas production and quality.

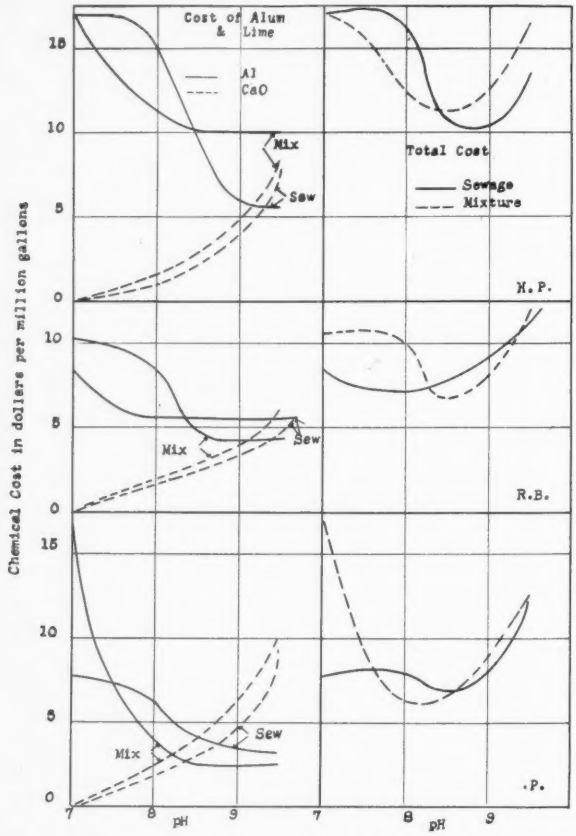
Professor Malcolm.—From what I observe, no. The content of the gas is changeable under normal conditions. Because of variable production rates it is essential that you have a gasometer or gas storage tank on the system.

Mr. M. M. Cohn.—Mr. Enslow has touched on a very important point. It is in line with Mr. Emerson's, and we should not become confused. We should not do anything which might affect a present important trend in sewage treatment; and perhaps one important trend is utilization of gas produced by use of gas engines. There may be some beneficial results from the addition of more digestible solids, and it is significant to point out that at the City of Durham, North Carolina, addition of properly macerated garbage to the sewage flow has increased gas production, resulting in more power and better utility balance.

CORRECTION—CHEMICAL COAGULATION OF SEWAGE. VII. EFFECT OF GARBAGE

Volume 9, Pages 406–424 (May, 1937)

In discussing the minimum increase in cost of chemicals when 100 per cent garbage was added (p. 423) the statement is made that the minimum additional cost for lime and ferric chloride was from \$0.60 to \$1.00 per million gallons, depending upon the type of sewage, and the minimum increase in cost for lime and alum treatment varied from \$0.45 to \$0.60 per million gallons. The latter figures should have been



from a maximum decrease in cost of \$0.50 to a minimum increase in cost of \$0.90 per million gallons. This is illustrated in the accompanying corrected figure. Part of the lower minimum cost is due to the fact that the optimum point of coagulation with alum is lower than for ferric chloride, so that less lime for reaction adjustment is needed.

WILLEM RUDOLFS,
ROBERT S. INGOLS

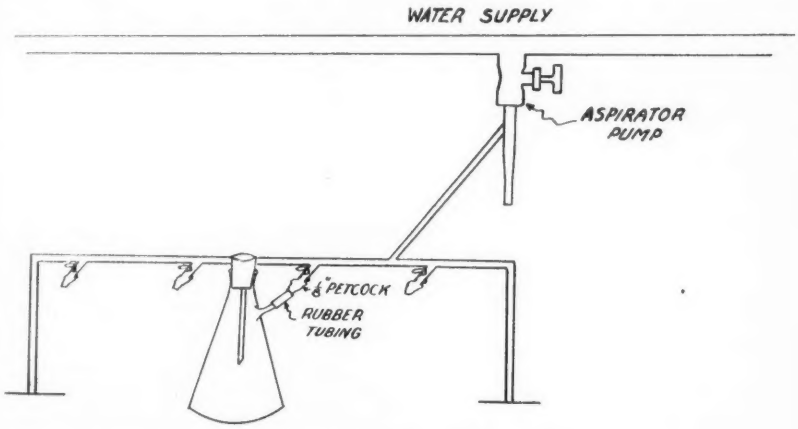
Operators' Reports and Suggestions

W. D. Hatfield

219 Linden Place, Decatur, Illinois

MICHIGAN STATE SEWAGE WORKS ASSOCIATION GADGET CONTEST

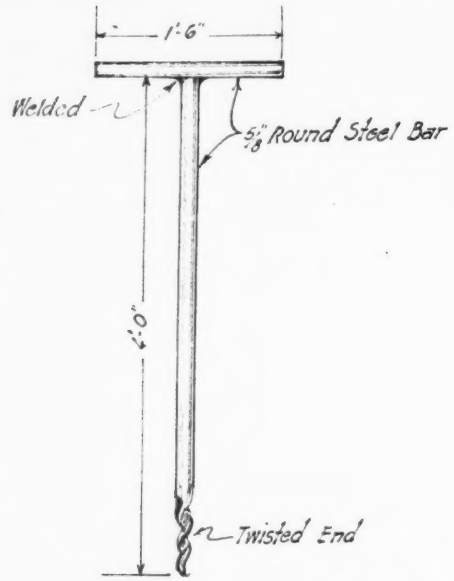
East Lansing, April, 1937



First Award: Manifold for Vacuum Filtration.

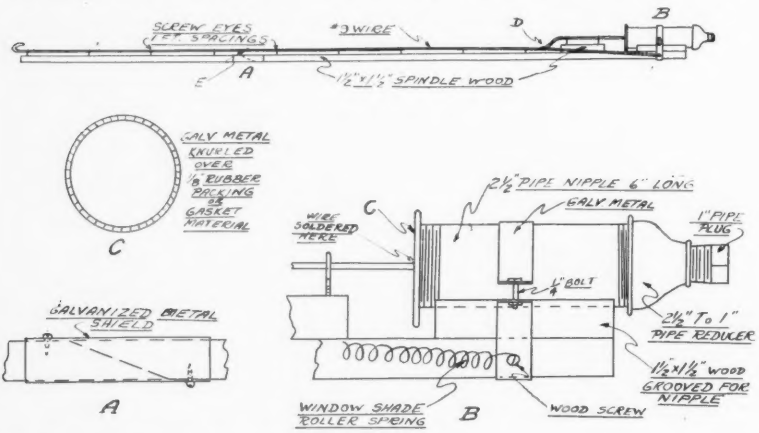
By R. A. Greene, *Asst. Supt. and Chemist, Jackson, Michigan*

This gadget is made of ⅛ inch gas pipe with ⅛ by ⅛ by ⅛ T's serving as connections. A petcock is screwed into each T. All of these connections are air tight. This is connected to an aspirator pump and will allow one to make four filtrations, each independent of the other.



Second Award: Gimlet Gaff for removing rags and other matter from sludge pumps and lines.

By L. J. Wolohan, *Division of Sewage, City of Dearborn, Mich.*



Third Award: Digester Sampler.

By Harold L. Smith, *Superintendent, Sewage Treatment Works, Alma, Michigan*

This sampler is used to take samples in a digester at given levels of sludge without sludge from other levels entering into the sample.

It is made of the following parts:

One piece of 1½ in. by 1½ in. spindle wood stock, spliced if necessary for length.

One 2½ in. pipe nipple 6 in. long.

One 2½ in. to 1 in. pipe reducer.
One 1 in. pipe plug.
One window shade roller spring.
Three or four wood screws.
A small amount of galvanized metal.
A small number of screw eyes placed on one foot centers.

The sampler is held on the rod by use of a strip of galvanized metal and bolt, as shown on drawing, the window shade spring is used for keeping the lid closed and is of the right tension for opening. The screw eyes are placed on one foot centers to be used for measuring the depth of the sample. The lid (section *C*) is made by knurling the edges of a circular piece of galvanized metal, around a piece of ⅛ in. rubber gasket material, slotting the edges if necessary. At point *D* the no. 9 wire has a small loop on each end of wire and is bolted together with a ¼ in. bolt for use as a flexible joint, also the same is used at point *E* for use in dividing the rod for storing. A small box is used for setting the sampler on, after the sample is taken, and the pipe plug is removed and sample drained into sample bottle. The sampler will draw about two-thirds of a pint at each sample. The complete rod will pass through a 6 in. sampling hole in the top of the digester.

CITY OF CEDAR RAPIDS, IOWA, SEWAGE TREATMENT PLANT, FIRST ANNUAL OPERATION REPORT APRIL 1, 1936 TO MARCH 31, 1937

By J. C. McIntyre
Plant Engineer
W. W. Walker
Chemist

The treatment plant was operated throughout the fiscal year with but few minor difficulties. In regard to the mechanical equipment some trouble was experienced with the mechanically raked screen. This was due to misalignment and after correction no trouble was experienced.

The gas engine was shut down three days in April for a general inspection and ten days in July for a complete inspection and cleaning. One main bearing was found to be badly burned and was replaced. Oil was changed in the engine every two weeks and the valves were ground every three months. Other mechanical troubles were considered as regular maintenance work. A leak in the gas line in one digester necessitated the draining down of the digester to complete the repairs.

Secondary treatment of the sewage was by-passed two days in February due to severe cold wave and four days in March due to flood stage of the river.

Trickling filters were flooded every eight days from April 27th to September 1st to control filter flies. No trouble was experienced in the operation of the filters.

A considerable amount of digested sludge cake was given away as a soil conditioner and the balance was used as fill in a low area on the plant grounds.

Pre-treatment of packing house wastes was accomplished without difficulties.

Experimental work was carried out by the Dorr Company twenty days in May, eleven days in June, twelve days in November and eighteen days in December on the pre-treatment plant.

Visitors from Australia, China, Canada, Holland, South America and most of the States of the Union were shown through the plant during the year.

Landscaping work on the grounds is being carried on and it is hoped that in another year the treatment plant will present a pleasing view as well as efficient operation.

Results on operation are summarized in the following tables.

TABLE I.—*Cost of Operation*

Payrolls	$15,575.73
Electric power	2,668.80
Insurance	1,521.93
Plant chemicals	329.15
Plant supplies	288.39
Electric supplies	54.08
Lab. expense	286.37
Office supplies	66.70
Telephone	80.84
Car and truck expense	170.34
Building maintenance	249.06
Grounds maintenance	55.08
Equipment maintenance	808.21
Gas engine expense	1,032.38
Miscel. expense	269.22
Total cost	23,456.28
Cost per M.G. treated	8.45

TABLE II.—*Gas Engine Operation*

K.W.H. generated	1,072,570
Per cent rated capacity	82
Hours in service	8,387
Per cent time in service	95
Gas used cu. ft.	28,950,900
Cu. ft. gas per K.W.H.	27
Cu. ft. gas per H.P.H.	16
B.T.U. per K.W.H.	16,200
B.T.U. per H.P.H.	9,940
Lubricating oil gals.	876
Gals. oil per 1000 K.W.H.	0.8
Gals. oil per 1000 H.P.H.	0.5
B.T.U. recovered from cooling water as digester heat	3,504 mil.
Cost per K.W.H. including charges for operation and investment	2.9 mills

TABLE III.—*Packinghouse Wastes Pretreatment*

Month 1936–37	Flow M.G.D.	$FeCl_3$ Gr./Gal.	Lime Lbs./M.G.	Raw		Primary Clar. Effl.				Secondary Clar. Effl.			
						B.O.D.		Susp. Solids		B.O.D.		Susp. Solids	
				5-day B.O.D. P.P.M.	Susp. Solids P.P.M.	P.P.M.	% Red.	P.P.M.	% Red.	P.P.M.	% Red.	P.P.M.	% Red.
Apr.	1.203	.....	830	796	477	626	21.1	215	54.4	535	29.9	151	67.5
May	1.218	.....	.....	630	491	483	22.3	186	61.2	464	25.3	137	71.7
June	1.115	1.8	600	724	536	519	28.5	164	67.8	522	28.1	148	72.0
July	1.040	2.0	515	750	543	542	28.3	168	67.6	513	29.7	153	70.5
Aug.	1.140	1.4	.....	715	544	513	27.1	211	60.9	492	30.5	169	68.3
Sept.	1.068	1.4	.....	564	530	412	26.7	184	64.2	359	36.1	137	72.7
Oct.	1.058	.....	.....	641	522	470	26.0	204	60.0	404	36.3	148	70.3
Nov.	—	—	—	—	—	—	—	—	—	—	—	—	—
Dec.	1.318	.....	.....	1169	815	614	45.9	180	74.0	556	51.1	125	80.1
Jan.	1.285	.....	.....	979	644	681	29.1	202	67.1	625	33.0	147	75.7
Feb.	1.349	.....	.....	671	580	413	36.2	121	77.9	426	33.6	125	76.5
Mar.	1.422	.....	.....	594	478	355	40.2	107	76.5	363	38.7	110	75.9
Avg.	1.201	.....	.....	748	560	512	30.1	177	66.5	478	33.8	141	72.8
Max.	1.422	.....	.....	1169	815	681	45.9	215	77.9	625	51.1	169	80.1
Min.	1.040	.....	.....	564	478	355	21.1	107	54.4	359	25.3	110	67.5

TABLE IV.—*Operating Data*

Month 1936–37	Connected Population	Population Equivalent 15 B.O.D. per Cap. per Day in 1000's	City Sewage M.G.D.	Packinghouse Sewage M.G.D.	Total Sewage Treated M.G.D.	Grit Removed Cu. Ft. per Day	Solids Removed Ton per Day	K.W.H. Used per Day	K.W.H. Generated per Day	K.W.H. Purchased per Day	K.W.H. Sold per Day	Lbs. Vol. Solids Added to Dig. per Day in 1000's	Gas Produced per Day in 1000 Cu. Ft.	Cu. Ft. Gas per Cap. per Day Actual Pop.	Cu. Ft. Gas per Cap. per Day Equiv. Pop.	Cu. Ft. Gas per Lb. Vol. Solids Added	Gas Utilized per Day in 1000 Cu. Ft.	B.T.U. Gas
Apr.	55,000	174.7	9.006	1.203	10.209	27	8.7	2020	3460	20	1450	13.2	130.6	2.37	0.75	10.1	102.6	623
May	.....	189.3	5.760	1.218	6.978	24	9.6	2075	3571	13	1500	14.8	146.0	2.65	0.77	10.1	99.6	—
June	.....	103.3	4.763	1.115	5.878	27	10.2	2046	3653	0	1607	15.6	147.4	2.68	1.40	10.0	99.8	—
July	.....	114.0	4.578	1.040	5.618	24	8.7	1740	1540	840	640	13.5	132.8	2.41	1.17	10.4	77.8	613
Aug.	.....	145.6	7.315	1.140	8.455	25	8.9	1790	2635	0	845	13.9	138.9	2.54	0.95	10.4	91.1	—
Sept.	.....	122.0	7.780	1.068	8.848	28	10.0	2012	2763	0	750	15.2	139.6	2.54	1.14	9.6	91.1	594
Oct.	.....	150.2	6.371	1.058	7.429	26	8.9	1848	2800	0	953	13.8	132.8	2.41	0.88	9.1	99.8	—
Nov.	.....	197.3	6.652	—	6.652	26	9.3	1730	2600	100	970	14.5	136.9	2.49	0.70	9.4	97.9	597
Dec.	.....	236.0	6.426	1.318	7.744	26	11.7	2140	3060	0	910	18.5	176.1	3.20	0.75	9.6	109.5	593
Jan.	.....	218.0	6.086	1.285	7.371	24	11.3	2102	3106	0	1004	18.1	165.4	3.00	0.75	9.1	105.9	609
Feb.	.....	179.0	6.921	1.349	8.270	30	12.3	2210	3075	10	876	19.2	144.4	2.62	0.81	7.5	102.7	588
Mar.	.....	210.7	9.846	1.422	11.268	32	13.6	2630	3052	133	567	19.3	126.7	2.30	0.60	7.4	98.4	—
Avg.	.....	170.0	6.792	1.201	7.893	27	10.3	2029	2943	93	1006	15.8	143.1	2.60	0.89	9.4	97.9	602
Max.	.....	236.0	9.846	1.422	11.268	32	13.6	2630	3653	840	1607	19.3	176.1	3.20	1.17	10.4	109.5	623
Min.	.....	103.3	4.578	1.040	5.618	24	8.7	1730	1540	0	567	13.2	126.7	2.30	0.60	7.4	77.8	588

TABLE V.—*Analytical Data*

Month 1936–37	Flow M.G.D.	Raw		Primary Clari. Effl.				Final Effluent			
		B.O.D. P.P.M.	Susp. Solids P.P.M.	B.O.D.		Susp. Solids		B.O.D.		Susp. Solids	
				P.P.M.	% Red.	P.P.M.	% Red.	P.P.M.	% Red.	P.P.M.	% Red.
April	9.006	376	343	268	29.2	133	60.0	68	81.5	102	69.7
May	5.760	452	361	348	22.2	139	60.6	84	81.2	59	82.8
June	4.763	317	328	237	24.8	118	62.5	45	85.7	42	86.7
July	4.578	332	296	245	25.2	108	62.9	39	88.2	36	87.4
Aug.	7.315	358	354	273	24.1	117	64.7	36	90.0	31	90.5
Sept.	7.780	282	348	213	25.2	118	64.0	37	86.4	46	85.7
Oct.	6.371	317	364	244	23.2	117	66.8	48	84.8	64	81.9
Nov.	6.652	484	480	340	30.6	127	72.8	67	85.7	61	86.8
Dec.	6.426	596	562	376	34.8	128	72.6	84	84.8	93	82.4
Jan.	6.086	443	348	321	26.3	125	62.6	87	79.7	81	76.0
Feb.	6.921	345	348	275	21.1	133	60.8	85	74.7	79	76.6
Mar.	9.846	353	343	258	25.6	132	59.7	59	82.6	78	75.5
Avg.	6.792	388	373	283	26.0	125	64.2	62	83.8	64	81.8
Max.	9.846	596	562	376	34.8	139	72.8	87	90.0	102	90.5
Min.	4.578	282	296	213	21.1	108	59.7	36	74.7	31	69.7

TABLE VI.—*Trickling Filter Loadings*

Month 1936–37	Days in Service	Lbs. B.O.D. Load /A./Da.	Lbs. B.O.D. Load /A. Ft./Da.	Max. B.O.D. Load /A. Ft./Da.	Lbs. B.O.D. Removed /A./Da.	Lbs. B.O.D. Removed /A. Ft./Da.	Max. B.O.D. Removed /A. Ft./Da.
April	30	6697	1030	1250	5004	800	994
May	31	7357	1132	1656	5582	858	1382
June	30	4553	700	1013	3760	578	853
July	31	4895	753	923	3740	575	819
Aug.	31	6852	1085	1456	6012	925	1192
Sept.	30	4663	717	882	3427	527	785
Oct.	31	3710	570	871	3015	464	658
Nov.	30	5064	779	1093	4034	620	910
Dec.	31	6312	971	1434	4934	759	1170
Jan.	31	6133	943	1473	4327	665	1123
Feb.	26	4921	757	1365	3503	539	957
Mar.	28	6009	924	1426	4733	728	1161
Avg.	30	5597	863	1237	4340	670	1000
Max.	.....	7357	1132	1656	6012	925	1382
Min.	.....	3710	570	871	3015	464	658

TABLE VII.—*Digester Loadings*

	Month 1936–37	Lbs. Solids Added per Month	Rate of Addition of Solids—Lbs. per Cu. Ft. Capacity per 30 Days	Lbs. Vol. Solids Added per Month	Lbs. Solids Added Max. Day	Max. Rate Lbs. Solids Added per Cu. Ft. Capacity per 30 Days	Lbs. Solids Drawn per Month	Lbs. Vol. Solids Drawn per Month	% Reduction Total Solids	% Reduction Vol. Solids
Dig. No. 1	Apr.	244,000	8.23	185,800	25,100	11.6	193,250	100,100	20.6	45.6
	May	302,000	9.40	231,500	29,800	13.8	120,500	67,500	60.4	70.9
	June	306,000	9.05	233,500	34,000	15.7	121,250	66,800	60.1	71.4
	July	272,000	7.90	212,000	23,000	10.6	113,200	62,400	58.4	70.6
	Aug.	281,000	7.93	218,500	20,200	9.3	139,800	69,300	52.0	68.4
	Sept.	254,300	9.48	195,000	26,900	12.4	75,200	43,800	70.5	77.6
	Oct.	234,000	8.18	182,000	21,750	10.1	161,500	91,900	30.8	49.6
	Nov.	223,000	8.57	173,500	23,100	10.6	100,050	45,300	55.0	73.9
	Dec.	266,190	8.77	208,250	37,600	17.3	160,820	91,000	39.7	66.4
	Jan.	284,250	10.07	230,250	27,400	12.6	156,100	91,840	45.0	60.2
	Feb.	231,200	11.87	176,850	33,800	15.6	35,550	20,810	84.6	88.2
	Mar.	270,230	10.38	191,250	34,500	15.9	56,900	31,830	79.0	83.3
	Avg.	264,014	9.15	203,200	28,100	13.0	119,510	65,215	54.7	68.8
Dig. No. 2	Apr.	277,000	7.84	212,000	24,700	11.4	183,500	100,750	33.4	52.5
	May	293,000	8.48	226,000	26,300	12.1	83,000	45,600	71.7	79.8
	June	310,000	9.58	236,500	29,000	13.4	114,600	63,000	63.0	73.4
	July	268,000	7.50	208,700	21,100	9.8	85,700	46,300	68.0	77.8
	Aug.	273,000	8.02	212,500	21,500	9.9	131,300	61,600	51.8	71.0
	Sept.	348,000	9.04	252,500	28,800	13.3	106,300	56,600	69.4	77.6
	Oct.	316,000	8.12	247,000	23,300	10.8	80,900	47,200	74.5	80.9
	Nov.	205,000	8.59	159,500	21,100	9.8	120,200	59,300	41.2	62.8
	Dec.	273,290	8.42	212,130	29,800	13.8	126,460	74,500	53.6	64.9
	Jan.	237,550	9.96	190,900	25,600	11.8	87,730	48,080	63.1	74.8
	Feb.	213,100	9.83	166,450	30,400	14.0	17,790	12,090	91.7	92.8
	Mar.	373,600	14.37	258,700	48,000	22.1	92,560	49,760	75.2	80.8
	Avg.	282,262	9.15	215,240	27,467	12.7	102,503	55,400	63.0	74.1
Gas Holder	Apr.	.....	.....	.....	.....	.....	.....	.....	.....	.....
	May	.....	.....	.....	.....	.....	.....	.....	.....	.....
	June	.....	.....	.....	.....	.....	.....	.....	.....	.....
	July	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Aug.	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Sept.	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Oct.	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Nov.	128,500	8.48	100,000	19,200	8.9	90,860	44,700	30.0	55.3
	Dec.	187,230	9.62	144,085	30,400	14.0	90,380	49,000	51.8	66.0
	Jan.	216,600	11.10	164,150	27,600	12.7	104,200	57,890	51.8	64.8
	Feb.	246,250	11.36	187,750	41,700	19.2	99,700	57,180	59.6	69.6
	Mar.	198,600	11.44	145,450	33,800	15.6	40,190	23,450	79.8	83.9
	Avg.	195,436	10.40	148,287	30,540	14.1	85,060	46,444	54.6	67.9

Note.—In Table III the two clarifiers were in parallel during the months of July, February and March. In November the packing plant sewage was treated with the city sewage while experimental work was being carried on. The effluent from the pretreatment receives

secondary treatment with the city sewage through the trickling filters. In Table V the final effluent is a combination of city and packing plant wastes. In Table VII the gas holder was used merely as a sludge storage and secondary digester during the months of April to October inclusive. In Table VI the pounds of B.O.D. removed include the removal by the secondary clarifiers.

REMARKS BY A. F. DAPPERT, CHAIRMAN OF THE RATING COMMITTEE, ON THE OCCASION OF THE PRESENTATION OF THE NEW YORK STATE SEWAGE WORKS ASSOCIATION'S ANNUAL OPERATOR'S AWARD TO MR. HERBERT O. JOHNSON AT THE UTICA MEETING, JUNE, 1937

It now becomes my pleasant duty to bring to a close the second year's rating project of this Association. But before proceeding with the ceremonies appropriate to the occasion it would seem desirable to make a few remarks concerning our Rating Plan, under which operators submit to the Rating Committee annual reports covering twelve months operation of their plants.

The whole idea of the rating project may be summarized by saying that it is designed to elevate the standards of plant operation and stimulate the preservation of essential operating data in a form suitable for dissemination. It is a project wholly for and by the plant operators. It affords an opportunity for all operators to make a valuable and distinct contribution to the advancement of the science of sewage treatment and to receive in a small measure at least some recognition and credit for their cooperative efforts.

Operators in making their reports follow in detail the form of report and schedules prescribed by the Rating Committee. The reports are reviewed by the Committee and graded in accordance with the scale of credits set up in the schedules and in June of each year the Association's Operator's Award is made to the person who submits the report achieving the highest rating. It is to be observed that the Rating Plan is in no way based upon the type or size of treatment plants nor upon the accomplishments of the plants. The plan is fair and equitable to all operators alike. The operator of a small simple plant has an equal chance with the operator of a large or more complex plant to achieve the honor of submitting the winning report. The Rating Plan essentially rewards the individual initiative of the operators, for the work of preparing the report is largely a task that must be undertaken as an "extra-curricular" activity—a service rendered to the community in some measure beyond the line of duty.

Every operator who has cooperated with the Rating Committee in this project is deserving of the highest praise and commendation of this Association. Let their names be engrossed upon our honor roll of

cooperating operators to receive such encouragement and gratitude as is possible for us as a group or as individuals to display. Listed alphabetically these are the operators who this year have achieved this signal distinction:

Mr. Charles Danisch—Central Islip State Hospital
Mr. V. E. Haemmerlein—East Aurora
Mr. Herbert O. Johnson—Belgrave Sewer District
Mr. E. A. Marshall—Geneva
Mr. George Mathers—Garden City
Mr. Channel Samson—Tonawanda Sewer District
Mr. Sherman Skinner—Monticello

Although there has been some decrease in the number of reports submitted to the Rating Committee in comparison with last year, this

lack in numbers is more than compensated for by the quality of the reports submitted. The Rating Committee will see to it that appropriate letters are sent to each of these operators and their respective officials in recognition of the distinguished service which they have rendered.

Last year you will recall that the Operator's Award was made to Mr. C. George Andersen, of Rockville Centre. At this point I should like to thank Mr. Andersen in behalf of this Association for his cooperation in submitting a report again this year. Being the recipient of last year's award his report this year was not submitted in competition but as a display of his interest in the continued success of the rating project. Mr. Andersen has brought with him copies of his report for distribution at this meeting, which are available at the registration desk.

Let us turn now to the ceremonies designed to do honor to the operator who has won the distinction of submitting the report which achieved

the highest rating this year. He has turned over to me a limited number of copies of his report, which because the number is limited, will be mailed at an early date first of all to the operator members of the Association and then to those who register sufficient interest in the report to write me for a copy.

This year because of the high merit and excellence of the report submitted, the Rating Committee has been forced to return to Long Island in its selection of the recipient of the award. I may say that his report achieved a rating which approximated perfection. When you see a copy of it I know that you will agree with me that it reflects the work of an operator who is intensely interested in his work and who has applied his talents vigorously in achieving maximum results from his plant at minimum cost. Need any more be said in praise and recognition of his services, except perhaps to remind the Commissioners of the Belgrave Sewer District that they have an operator who in no small measure has also brought the reflection of honor and distinction upon them?

Mr. Johnson, as operator of the sewage treatment plant of the Belgrave Sewer District you are awarded this loving cup by the New York State Sewage Works Association, in recognition of the distinguished service you have rendered in the advancement of the science of sewage treatment, which depends no less upon the practical results achieved through intelligent plant operation than upon developments in the fields of sewage research. May this token of our respect and admiration serve in future years to be a constant reminder of the heights to which you have risen in the estimation of your fellow workers and a source of inspiration to you in the continued progress of your work.

BELGRAVE SEWER DISTRICT, GREAT NECK, NEW YORK

1936 REPORT OF OPERATION OF THE SEWAGE TREATMENT WORKS, BELGRAVE SEWER DISTRICT *

Prepared in Accordance with the Outline Drawn up by the Rating Committee of the New York State Sewage Works Association

TOWN BOARD
TOWN OF NORTH HEMPSTEAD

Charles Snedeker, *Supervisor*
Hunter L. Delatour, *Councilman*
George C. Wallingford, *Councilman*
August Gleichmann, *Councilman*
Charles H. Hechler, *Councilman*

BOARD OF COMMISSIONERS
BELGRAVE SEWER DISTRICT

John O. Carter, *Chairman*
Alexander W. Berberich
Edward J. Byrnes, Jr.

Carl H. Watson, *Designing Engineer*

* *Editor's Note.*—This Report is presented in practically its complete form, except for slight condensation and elimination of some of the monthly data in the tables.

Rating Committee

New York State Sewage Works Association
Anselmo F. Dappert, *Chairman*
Wellington Donaldson
John R. Downes

Schedule 1

The Belgrave Sewer District is a "special improvement district" in the Town of North Hempstead, Nassau County, New York, and was established in 1928. Included within its boundaries are the Incorporated Village of Russell Gardens, portions of the Incorporated Village of Great Neck Plaza, the Incorporated Village of Thomaston, and the unincorporated area of the Town of North Hempstead. It is almost entirely residential in character, with a small business district, and a small undeveloped industrial section. It is located in the extreme northwestern corner of Nassau County adjacent to the New York City line.

The Sewage Treatment Works of the District is on the marshlands at the head of the easterly branch of Little Neck Bay in the Incorporated Village of Great Neck Estates. It was constructed in 1934 and 1935 as a non-Federal P.W.A. project. The drainage area comprises approximately 1,300 acres, about one-half of which is included within the present boundaries of the District.

The plant is of the separate sludge digestion type, modern and complete. The layout and exterior design conform to the general architectural treatment of the estates and homes in this vicinity.

1. The sewage treatment processes are as follows:
   (*a*) Manually cleaned bar screen.
   (*b*) Mechanically cleaned sedimentation basin divided longitudinally into two tanks.
   (*c*) Chlorination—either pre-, post-, or split.
   (*d*) Dilution of effluent in the tidal waters of Little Neck Bay.
2. Sludge treatment and accessory processes are as follows:
   (*a*) Heated sludge digestion tank with mechanical agitation.
   (*b*) Glass covered drying bed.
   (*c*) Sludge pulverizer. (Designed and built at plant.)
   (*d*) Flame protective device. (Designed and built at plant.)
3. The lands within the District drain to Long Island Sound with an average slope of approximately 150 feet per mile. Through careful engineering design of the trunk sewers, the entire system leading to, through and from the plant permits gravity flow. Scouring velocities are obtained generally throughout the District. This condition, together with relatively steep grades, results in a fresh sewage being delivered to the plant at all times. Effluent from the plant flows through 3,000 feet of 24 inch outfall into Little Neck Bay.
4. Actual plant operation began September 20, 1935.
5. Design basis of original sewage works as to volume of sewage to be treated and population to be served:
   After a careful study of past population data and future trends for like areas, a plant design was adopted to treat 1,000,000 g.p.d. contributed by an estimated population of 12,500.
6. Date and nature of subsequent additions:
   None.
7. Present population served and how obtained:
   It is estimated that the present population connected to the sewers is approximately 3,000. This figure was obtained by analysis of a census taken by District employees.
8. Separate or combined sewers and percentage of each:
   The sewer system contributary to the plant is 100 per cent separate. State Health Department regulations forbid the entry of storm waters either through roof leaders, yard drains, gutters, etc., and every effort is made to prevent their connection to the system.

9. Storm water diversion outlets or bypasses, etc.:
None.

10. Nature and importance of industrial wastes tributary to sewer system:
There are at present no great amount of industrial wastes contributed other than from one laundry, one carpet cleaning establishment and several garages. All garages are required to pass their wastes through sand and oil separators before discharging to sewer. Periodic inspections of the separators insure their efficient operation.

11. Method of measuring or estimating sewage flow:
No means for measuring the sewage flow was provided in the original design. An approximate estimate has been made at intervals by diverting the flow into the settling tank not in use and recording the time required to raise the water level through measured increments. Further information on instantaneous rates of flow has been obtained by barrel and stopwatch tests.

12. General purpose of sewage treatment:
The chief purpose of the Sewage Treatment Works of the Belgrave Sewer District is to prevent at this point pollution of the waters of Little Neck Bay and Long Island Sound.

13. Are separate meters available at plant for proportioning power consumed by various processes?
One meter is provided to measure total power consumption and one for light consumption.

14. Total electric power used in k.w.h.:

Total for 1936	3,689 k.w.h.
Avg. per Month	307 k.w.h.

15, 16, 17. Average daily sewage flow entering plant:
The estimated average flow is 0.30 m.g.d., min. 0.10 and max. 0.70 m.g.d.

18. List of employees and time of each spent on plant operation and maintenance:

	Plant Proper	Sewer Dist.
(*a*) Superintendent	40%	60%
(*b*) Operator	50%	50%
(*c*) Part Time Labor	100%	—

In addition to operation and maintenance of the plant, the above employees also maintain 18 miles of sewers, and attend to the general administration of Sewer District affairs.

SCHEDULE 2

C. Coarse Screens:

1. All sewage passes manually cleaned bar screen located in a small building one-quarter mile upstream from the plant. The screen is a 24 in. wide galvanized iron rack set at an angle of 45 degrees to the flow. The clear opening between bars is 1½ inches.
2. Screenings are permitted to accumulate on the rack and are removed daily.
3. Screenings were removed in 1936 as follows:

Total Screenings Removed	183.0	Cu. Ft.
Average Screenings Removed per Month	15.2	Cu. Ft.
Cubic Feet per M.G.	1.68	Cu. Ft.

4. Screenings are collected in a galvanized iron bucket with perforated bottom suspended over the sewer channel. After draining, they are transported to a dump and covered with a minimum of six inches of dirt.

G. Primary Sedimentation (Tanks with mechanical equipment):

1. The sedimentation basin is divided longitudinally into two rectangular, horizontal flow, flat bottom tanks with sludge collection hoppers at the influent end. Sewage is conducted from the incoming sewer through a valved inlet which permits the use of either tank or both in parallel. The inlet ends of the tanks are provided with distribution channels having submerged inlet ports in front of which is placed a submerged steel baffle plate. At the effluent end of the tanks is a scum trough which also serves as a baffle. There exists also an overflow weir and sewage collection trough.

   Each tank is equipped with a Hardinge Company mechanical sludge scraping and skimming mechanism. The unit (riding on rails) is essentially a crane spanning the tank. Structural members carry a scraping unit along the floor, which pushes sludge to and into the hopper at the influent end of the tank. As the mechanism reverses (to go to the effluent end of the tank) a tripping lever revolves the scraper through 90 degrees to a position parallel to and about 14 in. above the floor. The skimming device then engages the surface of the sewage and carries all floating solids to the scum trough. The rate of travel of the scraper is three feet per minute.

   The sedimentation tanks are covered with a standard greenhouse type glassover.

   Each tank is 60 ft. long and 12 ft. wide, with a sewage depth of 8.7 ft., and a freeboard of 4.3 ft. The capacity of each unit is 6,264 cu. ft., or 46,980 gallons. Total capacity of both tanks is 93,960 gallons.
2. Throughout the year 1936 only one tank was in operation. Based upon estimated average flow of 0.30 m.g.d. a theoretical detention period of 3.76 hours was obtained.
3. After considerable observation of the efficiency and effect obtained by operating the scraper for different periods at various times of the day, the following routine was found to be most favorable:

   The scraper is started at 10:00 A.M., shortly before the morning peak flow reaches the plant, and runs continuously until about 1:30 P.M. Pumping of raw solids from the hopper is started about 15 minutes before the scraper reaches the hopper on the last traverse. The mechanism is operated only once a day.
4. Raw sludge is pumped from the hoppers to the digester once daily. Pumping is begun a short time before the scraper reaches the hopper, and continues until the sludge becomes "thin." Although the hopper sides are sloped 45 degrees, slicing of the sides is required to remove all sludge. This is accomplished by a special slicing tool with 16 foot handle. The sludge discharge into the digester is visible, and the time of pumping is governed by observation. Pumping is done by two 4-inch piston type Marlow Mudhogs equipped with ball valves. Very little difficulty has been experienced with clogging.
5. Removal of raw sludge from the sedimentation tanks in 1936 was as follows:

Total Sludge Withdrawn	69,336	Cu. Ft.
Cubic Feet per M.G.	636.1	Cu. Ft.

6. There is no practical method of measuring skimmings at this plant. They are permitted to accumulate in the scum trough and are then pumped to the digester. An estimation based on observed quantities pumped, indicates that approximately 200 cu. ft. were removed during the year. There is approximately 1.8 cu. ft. per m.g.
7. A sample of raw sewage is collected each day at the times of peak flow for determination of settleable solids. Results were as follows:

Total Readings for 1936	366
Average of all Readings	6.67 cc. per liter
Maximum Reading	14.0 cc. per liter
Minimum Reading	1.0 cc. per liter

8. The effluent from the sedimentation tanks is sampled for settleable solids about three hours after the influent sample is taken. Results were as follows:

Total Readings for 1936	366
Average of all Readings	0.17 cc. per liter
Maximum Reading	0.50 cc. per liter
Minimum Reading	0.10 cc. per liter

Reduction of settleable solids through sedimentation:

Average annual cc. per liter in raw sewage	6.67
Average annual cc. per liter in effluent	0.17
Reduction	6.50
Per cent reduction	97.5

O. Chlorination:

1. Chlorination equipment consists of two Wallace & Tiernan manual control vacuum chlorinators, one 400 pound platform scale, and home-made delivery manifolds so designed that either machine can deliver chlorine for either pre- or post-chlorination. The equipment is located in an isolated room so that in the event of a chlorine leak no damage will result to electrical and mechanical equipment in the building. Storage for twenty-five cylinders is provided for in this room.
2. Chlorine may be applied for either pre- or post-chlorination. For pre-chlorination, a hose is run to a manhole in the influent sewer. After receiving the chlorine, sewage flows around two 90 degree turns before entering the sedimentation tanks. This insures good admixture of chlorine with the sewage. For chlorination of the effluent, a contact basin is provided at the end of the collection trough of the sedimentation tanks.
3. Provisions for pre-chlorination were made for odor control. To date this has not been necessary as the sewage reaches the plant in a relatively fresh condition with no offensive odors. The effluent from the plant is chlorinated heavily to further lower the B.O.D. of the settled sewage and reduce the organisms of the coli-aerogenes group to give negative results in 10 ml. portions sown.
4. Chlorine used in 1936 was as follows:

Total Pounds Used	9,650
Pounds per M.G.	88.5

5. The period of contact in the basin is 15 minutes. Sewage then passes through the outfall sewer, which provides an additional 15 minutes contact period before dilution in the tidal waters of Little Neck Bay.
6. Residual chlorine data:
   (*a*) Residual chlorine tests are made once a day on a sample collected at peak load. Average residual in 1936 was 1.0 p.p.m.
7. No equipment for bacteriological work is provided at this plant.

   Bacteriological analyses of the effluent were made at intervals by Thomas M. Riddick, associated with the late Nicholas S. Hill, Jr.

   Results are tabulated below:

Date	Total Bacteria Count per ml. 24 Hrs. at 37° C.	Coli-Aerogenes Group M.P.N. per 100 ml.
May 7	27	24*
June 9	90	23*
July 28	55	24*
September 2	38	24*
October 6	380	240
November 11	19	24*

* Less than.

Q. Sludge digestion tanks:

1. This plant is provided with one single-stage, heated digestion tank, 30 ft. in

diameter and 12 ft. deep (below the spring-line of the dome cover). The dome rises two feet four inches above the spring-line. Stirring of the contents of the tank is effected by a Hardinge type agitator, which revolves four revolutions per hour. This mechanism consists essentially of a central shaft carrying plows which force sludge to a suction pit. A scum breaker is located just below the dome. Motive power is furnished by a two H.P. motor through suitable reduction gears. The agitator is operated 24 hours a day. The total capacity of the tank is 9,200 cu. ft. Gas is collected in a steel gas dome three feet in diameter and three feet deep built into the top of the tank. It is provided with two gas outlets and a sprayhead to wash foam. A 12 in. water seal and manometer connection is provided. Gas produced is wasted to atmosphere through a flame trap designed and built at the plant. A series of measurements of the quantity produced recently, indicate that sufficient gas is being generated to justify the installation of equipment to heat the digester. Plans for this addition are now being made. Supernatant liquor displaced while pumping sludge may be taken from either of two riser pipes which extend to different depths in the tank. Located in the same manhole as the overflows are three pitcher pumps for sampling. These pumps draw sludge from levels 3, 6 and 9 ft. from the bottom of the digester. Raw sludge from the sedimentation tanks is discharged into the digester through a pipe located above the liquid level in an inspection manhole. This arrangement precludes the possibility of pumping air into the digester when the scum drain is being emptied. This construction also permits observation of the raw sludge being pumped from the sedimentation tanks.

A 300 ft. hot water heating coil is suspended in the digester about 4 in. from the wall. The pipe is 1½ in. in diameter and is provided with suitable swing connections for expansion and contraction. Hot water is circulated from a large heat-exchanger on the oil-fired boiler which heats the administration building. This arrangement is effective, but not economical, and it is to be used only until sufficient gas is produced to justify installation of gas heating equipment. Constant circulation is maintained by a small centrifugal pump, and the flow is metered. Thermometers are placed in the feed and return lines.

2. Digestion capacity used:

The entire capacity of the digester is used, as the tank is kept full at all times.

3, 4, 5, 6, 7, 8, 9.

The following data give information pertaining to the digester in 1936:

Month	Temp. F° Sludge	pH	Lime Added in Lbs.	Water Circulated Avg. G.P.D.	Temperature F°		Sludge Removed, Cu. Ft.
					Inlet Line	Return Line	
Jan.	62.9	7.0	0	4,371	—	—	0
Feb.	65.0	7.0	0	8,036	—	—	667
Mar.	77.2	7.0	0	10,396	112	99.4	1000
Apr.	79.2	7.0	0	8,788	109	96.6	1000
May	76.6	7.0	0	8,733	110	98.0	1166
June	69.6	6.9	0	—	—	—	0
July	68.0	6.8	0	—	—	—	2650
Aug.	68.0	6.8	0	—	—	—	1000
Sept.	67.5	6.8	0	—	—	—	1000
Oct.	64.0	6.7	400	—	—	—	1340
Nov.	61.1	6.8	800	9,137	106	88.0	1000
Dec.	71.0	7.0	0	8,477	118	101.7	1890

Average temperature of sludge	69.5	F°
Average pH of sludge	6.9	
Total lime used for conditioning	1,200.0	Lbs.
Average daily volume of circulating water	8,277.0	Gals.
Average temperature of feed water—inlet	111.1	F°
Average temperature of feed water—return	96.6	F°
Total volume of sludge removed	12,713	Cu. Ft.
Cubic feet of sludge removed per M.G.	116	Approx.

10. Cubic feet of sludge in tank:
    Approximately 8 ft. of sludge is kept in the tank at all times. This amounts to 5,600 cu. ft.
11. Supernatant liquor from the digester (which may be selected from either of two overflows extending to different levels) flows back to the raw sewage before it enters the sedimentation tanks. At no time during this year's operation has the supernatant caused any difficulty. Approximately one-half million gallons of supernatant was returned, representing about 0.41 per cent of the yearly sewage flow.
12. The digester was put in operation in September, 1935. It was filled with fresh sewage and raw sludge from the sedimentation tanks, and raw sludge was pumped daily thereafter. The initial pH of the digester sludge was 6.4. 700 pounds of lime were required over a two-week period to raise the pH to 7.0. Heating of the tank was a slow process, the temperature reaching 69 deg. F. by January 1, 1936. Agitation of the tank was continuous. No digested sludge was added for seeding. A slight foaming occurred on two occasions, but additions of small quantities of lime immediately cleared up this condition. Enlargement of the heating equipment resulted in higher temperatures which seemed to stabilize the sludge since no further foaming was noticed. Heating of the tank was discontinued in May for economic reasons since analyses showed good digestion. Temperature was then 84 F°. From this time on, temperatures dropped slowly to 59 F° in November, and the pH lowered from 7.0 to 6.6. Sludge withdrawn during this period was well digested but an increase in the organic content was noted, indicating that digestion was not as complete as when the tank was heated. In November heat was applied again and lime added to raise the pH to 7.0

R. Sludge Drying Beds:

1. The sludge drying bed (75 ft. long and 40 ft. wide) is covered with a standard greenhouse glassover. This has ventilating sashes in the peak and inswinging sashes on the sides. The bed is divided into three sections by low concrete partition walls. The entire area is available for drying since no walkways project over the sand. Control valves are manipulated through the side sashes. There is 6 in. of sand overlying 6 in. of crushed stone, in which are located the drain tiles. The total area of the bed is 3,000 sq. ft.
2. Several depths of sludge were applied to the beds experimentally, and it was found that 7 in. of digested sludge was best suited for Great Neck conditions.
3. The average pH of the sludge applied to the beds was 6.9 +.
4. Drying data:

Maximum time, days	31
Minimum time, days	11
Average time, days	17

5. No chemicals were used for conditioning digested sludge applied to the beds. It was at all times inoffensive as to odor, and dewatered readily. Analyses show a fairly low organic content.

6 and 7.

Wet sludge applied was measured by averaging the depths of sludge on the beds.

The quantity of wet sludge pumped to the beds, and quantity of air dried sludge removed, were as follows:

Month	Cu. Ft. Wet Sludge Applied	Cu. Ft. Dried Sludge Removed
January	0.0	0.0
February	667.0	0.0
March	1,000.0	410.0
April	1,000.0	200.0
May	1,166.0	333.0
June	0.0	333.0
July	2,650.0	415.0
August	1,000.0	440.0
September	1,000.0	280.0
October	1,340.0	200.0
November	1,000.0	440.0
December	1,890.0	420.0
	12,713.0 Cu. Ft.	3,471.0 Cu. Ft.
Cubic feet air dried sludge removed, per M.G.		31.8

8. Drainage from the sludge drying beds is collected by an underdrain system which discharges into a sand and gravel fill, 8 ft. below grade.

9. Sludge is removed from the beds by forking and is wheeled to a storage space. Odor from the stored sludge is that characteristic of humus and is in nowise objectionable. A chain mill type pulverizer (designed and built at the plant) reduces the dried sludge cake to a size which will pass a ½-in. mesh screen. In this form it is best suited for use as lawn dressing. All sludge produced has been so treated and used on lawns and shrubbery at the plant and in the District.

S. Sludge Analyses:

1. Laboratory equipment for this plant was purchased in late January, 1936, but regular analytical routine was not established for a few months due to press of other work incident to commencement of operation. Samples of digested sludge were analyzed twice a month, and of raw and dried sludge once a month. Samples were collected as follows:

Raw Sludge:

Raw sludge from the sedimentation tanks is discharged into the digester through a pipe located above the liquid level in a special manhole. Samples are taken at 2- or 3-minute intervals throughout the pumping period and composited. Analyses are made on a portion of this composite.

Digested Sludge:

Samples of digested sludge are collected in two ways: Samples of the sludge in the bottom of the digester are taken by means of the sampling pumps in the overflow manhole. A composite sample of digested sludge pumped onto the sand beds is also collected.

Air Dried Sludge:

Samples are taken at different parts of the beds as sludge is removed. Adhering sand is eliminated and a small sample is obtained by quartering. The following data give average results of all sludge determinations in 1936:

2. Dry solids—primary sludge 3.7%
Volatile content 69.4%
3. Dry solids—digested sludge 7.6%
Volatile content 45.3%

4. Dry solids—dried sludge 34.1%
   Volatile content 47.0%
5. Average pounds (dry basis) of raw sludge solids per million gallons treated annually 1,434.0
6. Average pounds (dry basis) of digested sludge solids per million gallons annually 604.0
7. Average pounds per capita daily of raw solids recovered as sludge annually 0.146

SCHEDULE 3

Analyses

The Commissioners of this District have provided a laboratory equipped to make solids determinations and chemical analyses. Equipment for D.O. and B.O.D. tests is being acquired. No B.O.D. tests were made at this plant in 1936. Independent analyses were made at intervals on raw and treated sewage by Thomas M. Riddick, associated with the late Nicholas S. Hill, Jr. Results of these analyses are given in various tables following:

A. Bar-screened Sewage:

1. Raw sewage after passing the bar-screen enters the inlet channel to the sedimentation tanks. The depth of sewage here is approximately 10 in., which causes a good scouring velocity. This assures obtaining a representative sample. Catch samples for solids determinations are taken in this channel between 10:00 and 11:00 A.M. at morning peak flows. Samples for the independent analyses are collected at four hour intervals over 24 hours.
2. No. B.O.D. tests were made at the plant in 1936.
3. Suspended Solids. Raw Sewage.

   No suspended solids tests were made duirng the first four months of the year for reasons stated under Section S in Schedule 2.

   The following data show the total and suspended solids of the raw sewage as analyzed in the plant laboratory:

Average p.p.m. suspended solids in bar-screened sewage for the year 180
Average p.p.m. total solids in bar-screened sewage for the year 546

The following results are averages of six independent analyses of the bar-screened sewage. Samples were composited at 4-hour intervals for a 24-hour period:

Average p.p.m. total solids 401
Average p.p.m. suspended solids 141
Average p.p.m. dissolved solids 259
Average 5-day 20° C. B.O.D. 225

C. Settled Effluent:

1. Settled sewage passes into a chlorine contact chamber with openings so arranged that samples may be taken of either chlorinated or unchlorinated effluent. Collections also may be taken in a junction manhole on the outfall sewer fifty feet below the plant. For solids determinations, catch samples are collected in this manhole at 1:00 P.M., three hours after collection of samples of raw sewage. This 3 hour difference corresponds roughly to the detention period in the tanks.
2. No B.O.D. tests were made at the plant in 1936.
3. Suspended Solids:

   No determinations of suspended solids in the effluent were made during the first four months of the year. The following average results were obtained thereafter:

Average p.p.m. of suspended solids in the effluent for the year 58
Average p.p.m. total solids in the effluent for the year 408

Summary of solids determinations made at the plant:

	Total Solids p.p.m.	Total Suspended p.p.m.	Total Dissolved p.p.m.
Influent	546	180	366
Effluent	408	58	350
Reduction	25%	67%	4%

The following data show average results of six independent analyses of the settled effluent:

Average p.p.m. total solids in effluent 328
Average p.p.m. suspended solids in effluent 43
Average p.p.m. dissolved solids in effluent 288
Average p.p.m. 5 day 20° C. B.O.D. in effluent 120

Summary of independent analyses:

	Total Solids p.p.m.	Total Suspended Solids p.p.m.	Total Dissolved Solids p.p.m.	5 Day 20° C. B.O.D. p.p.m.
Influent	401	141	259	225
Effluent	328	43	288	120
Reduction	18%	69%	—	47%

It is of interest to note that the per cent removal of suspended solids shown in the analyses of the commercial laboratory checks very closely with the removal shown in the plant laboratory. Results of the commercial laboratory are uniformly lower as would be expected due to different sampling procedure.

SCHEDULE 4

A.

1. Original cost of plant	$83,000.00
2. Cost of additions	0.00
Total cost	$83,000.00

B.

1. Salary of Superintendent chargeable to plant operation and maintenance		$1,492.00
2. Salaries of chemists, clerks, etc.		0.00
3. Wages of all labor		589.00
4. Total power costs—power and light		250.00
5. Chemicals:		
Chlorine	$ 532.00	
Lime	12.00	
	$ 564.00	564.00

6. Total miscellaneous:		
Water	$ 191.25	
Fuel oil	336.75	
Gasoline and oil	15.00	
General supplies	200.00	
Truck	95.00	
Insurance	268.00	
Telephone	75.00	
Laboratory supplies	35.00	
Chemical and bacteriological analyses	300.00	
	$1,516.00	1,516.00
7. Grand total of all expenses for year		$4,391.00
8. Revenue from disposal of cesspool contents		88.00
9. Net total operating and maintenance expense		4,303.00
10. Average cost per M.G. of sewage treated during the year		40.28

Respectfully submitted,
H. O. JOHNSON,
Superintendent

USE AND APPLICATION OF VARIABLE SPEED CONTROL *

BY H. B. DIEHL

Reeves Pulley Co., 76 Dey St., New York City

The application and use of variable speed in the sewage treatment field occupies an increasingly important position in treatment plant operation. Each of the mechanical units performing the various treatment process operations should be operated at variable speed, with a control to fit the particular application. A brief listing would include chemical feeders for both wet and dry chemicals, vacuum filters, sludge pumps and elevators, sludge dryers of the spray or oven type, incinerators, fine screens and flocculators.

In chemical treatment, particularly chlorination, a proportionate amount of chemicals should be fed to accomplish exactly the desired results without waste of chemicals. Dry chemicals may be added to the raw sewage at a speed proportionate to the flow, as measured by venturi meters.

The first automatic unit of this type was placed in operation early in 1935 in Perth Amboy. The differential pressure between the entrance and the throat of the venturi is transmitted to a diaphragm pendulum unit which operates a control potentiometer in an electric circuit. Across the whole of this potentiometer is applied 6 volts of direct current, and between the moving finger and one end of the potentiometer a voltage is delivered that is proportionate to the rate of flow. Opposed to the above voltage is the voltage generated by a tachometer generator, mounted on the output shaft of a variable speed drive, which produces a current of 6 volts at its maximum speed. A galvanometer relay is connected between the potentiometer and the tachometer generator and when the voltage delivered by the generator exactly equals that delivered by the potentiometer there will be no current passing through the galvanometer and it will stand at neutral or off position. Under these conditions there is no change in the rate of feed. When there is a change in flow the potentiometer finger moves and through an auxiliary power-relay an electric automatic control is operated to increase or decrease the speed of the variable shaft of the drive, in direct ratio to the volume of sewage flow-

* Presented at the Spring Meeting of the New York State Sewage Works Association, Utica, N. Y., June 3, 4, 5, 1937.

ing through the venturi. In this instance the drive is connected through a speed reducer to a conveying feeder which feeds lime, ferric chloride and paper pulp proportionate to the rate of flow as indicated by the position of the moving finger on the potentiometer.

A small rheostat in the potentiometer circuit provides the means for changing the ratio so that different "speeds to flow" proportions may be made. With this type of control it is possible to feed the chemicals or added agents in exact proportion to the rate of flow. A fluid pressure control that I will describe later offers an alternative to this electrical equipment.

Variable speed control is extremely important in vacuum filter dewatering of sludge; to illustrate, vacuum filters are used to dewater raw, digested raw, chemically precipitated and activated sludge, mixtures of these and mixtures of these and industrial wastes. It is obvious that there is a wide range of filtering characteristics that demand speed variation as well as chemical control. In the past, it was practice to maintain a constant sludge level in the filter pan or tank by delivering more sludge than the filter could dewater and overflowing the excess, either back to the original source of sludge or to a separate chamber, from which it was repumped into the filter feed. It was necessary, therefore, to re-treat the overflow sludge with conditioning chemicals, thereby increasing the cost of sludge dewatering. It was found that the filtrability of the sludge was more or less adversely affected by such treatment because of the additional time it was in contact with the conditioning chemicals and the additional agitation.

Several improved methods of control are now used, one in which the supply to the filter is controlled only by the rate of flow of the effluent from the sedimentation tanks. In this installation the speed of rotation of the filter drum is automatically controlled from a float in the filter tank. The Great Neck, Long Island, plant has an installation of this description.

Where the flow is fairly constant a manually set variable speed drive may be used.

The arrangement which seems to offer the best results and to be increasing in favor is where the filter drive speed is manually set and the speed of the sludge pump or elevator feeding to the filter is automatically controlled by the increase or decrease in liquid level in the filter tank. This results in a more constant submergence of the drum, permits the filter to be set at optimum speed, allows a constant vacuum to be maintained and discharges the sludge cake with a more uniform moisture content. In this type of installation the float controlled sludge conditioning and variable speed delivery from the pump or elevator also serves to compensate for changes in the filtering characteristics of the sludge. Filter drum speed is normally set at one revolution in two or two and one-half minutes, depending on the character and density of the sludge but to provide for the unusual but possible requirements a unit with a speed range of from one revolution in six minutes to one revolution in one minute is generally specified and any speed between these limits may be obtained. To illustrate the extent of this application on filters, 35 cities installed or specified over 100 sludge filters so equipped during the last five years. Chicago alone installed 28.

One of the latest developments in automatic mechanical control, particularly designed for sewage and kindred processing, is the fluid pressure control mentioned previously in this paper. Here a float operates a pilot valve, allowing compressed air or water at normal pressure to build up and maintain a pressure against the speed mechanism of the variable speed drive. This provides a speed setting that is proportionate to the position of the float. The fluid pressure control may also be used with a double diaphragm four-way valve, utilizing the varying pressure required to force a flow of air through a pipe immersed in the sludge, or in fact any liquid, to actuate the pilot valve. This pipe may be as small as 3/8 in. in diameter. The air passing from the end of this pipe will not permit it to become clogged. The merit of this control is that there is no float. The varying density of the liquid or sludge has the same effect as a change in liquid level and through the operation of the four-way valve a corresponding adjustment in speed is made.

Sludge cake incinerators of the multiple-hearth type require variable speed, particularly during the starting-up period, to determine the best shaft speed. Variable speed is also advantageous in continuous operation, as the sludge delivery in a normal

day may vary as much as 30 per cent and the time to complete the dewatering and incineration will vary with the amount of moisture in the cake, the character of the sludge and the degree of heat.

Variable speed has also proved its worth on continuous sludge dryers of the traveling pallet type. These units receive the sludge as discharged from the filters and the rate of travel of the pallet carriage is set exactly to deliver a completely dried sludge in the minimum time. Several factors determine this speed. The delivery rate of the sludge, its moisture content, thickness of the sludge bed deposited on the pallet, and the temperature and amount of air drawn through the bed are variables which demand variable speed control.

Another use of variable speed drives is in the sludge spray-drying process. Here the speed of the pump which delivers sludge to the spray nozzle is automatically controlled from the temperature of the vapor passing from the drying chamber.

Variable speed is advantageously applied to fine screens of the Reinsch-Wurl type. The first application of automatic variable speed control in the sewage treatment field was made in a screen of this type at South Norwalk. These drives were controlled from a float and they speeded up or slowed down the rotation of the screens in proportion to the amount and density of the solid matter deposited.

Flocculators for sewage or settling tank effluent driven at variable speed provide agitation of just the proper turbulence to promote the most rapid and efficient conditioning of the floc.

In closing, let me say that none of the great process industries could have reached their present rate of production without variable speed control. Take for instance the automobile assembly line. The speed for the day's production is set and all feeder conveyor speeds are coordinated. The mechanical flexibility of operation in the sewage disposal plant should equal if not exceed that in general manufacturing lines.

Discussion

By M. B. Tark

Link Belt Company, Philadelphia, Pa.

Mr. Diehl has mentioned many machines for which a variable speed drive is either essential, or desirable and economical. Instantaneous variation in speed may be obtained by means of several types of motors or mechanical units. Four speeds can be obtained by a multi-speed motor with several windings. A 1200 r.p.m. motor will also give speeds of 900, 600 and 450 r.p.m. at high efficiencies. The difference in speed is, however, so great that such a motor can rarely be used in connection with the equipment mentioned by Mr. Diehl.

Almost any variation in speed between a 2 to 1 ratio may be obtained by a slip-ring motor. The efficiency of such a motor drops very rapidly and as the speed of such a motor varies with load, a mechanical variable-speed transmission is in many cases preferable. To attain satisfactory results with such a unit, careful selection is essential. Efficiency, life, cost maintenance and first cost must be taken into consideration.

Investigation of the chemical coagulation process has shown the desirability of variable speed drives for the mixers. The success of the process depends upon four factors, one of which is speed of mixing paddles; the others are: amount of chemicals, area of mixing paddles, and time of detention in mixing tanks.

The time of detention in the mixing tank is usually fixed. So is the paddle area after the initial period of experimentation. The chemical dose will vary with the flow, and the speed of the mixers should also vary as the period of detention increases or decreases. The speed of the paddle mixers may be controlled by the same means as that of the chemical feeding apparatus. Larger plants have more than one mixing unit and in such cases it is advantageous to have a separate drive for each unit and to change the speed of each to suit varying conditions. For instance, during a high rate of flow, the first unit may run at a circumferential speed of 1.8 feet per second, the second at 1.4 f.p.s., the third at 1 f.p.s. As the flow goes down the speed of the first is reduced to 1.4

f.p.s. and that of the second to 1 f.p.s. At the lowest rate of flow all machines will run at 1 f.p.s. Over-mixing is just as detrimental as under-mixing and much work and worry may be eliminated by the installation of variable speed control units.

The economy of variable speed pumps is so well known that most modern pumping stations have at least one such unit. The pump in such installations is small, as the sewage is pumped at the rate received, instead of two or three times the rate, as was usual in the older small plants. The variation in water level in the pump is kept constant to within 6 inches so that the suction lift is practically eliminated. A mechanically variable speed drive is very desirable for such pumps, as the efficiency is high at all speeds. The motor operates at a constant speed and only takes the amount of current needed for driving the pump. The control for such a unit consists of a rotary switch added to the usual float control and switch. The wiring from the control switch to the small control motor is also very simple and does not involve any complicated mechanical or electrical mechanisms. A variable speed transmission is also advantageous in connection with centrifugal pumps for return activated sludge. The head is usually low and a very wide range of speeds may be obtained without sacrificing efficiency. The speed of the pump may be controlled manually or from the Venturi meter.

The high efficiency, the wide variation in speed obtainable and the simplicity of the control make a variable speed transmission a desirable drive for many units of the sewage treatment plant.

Editorial

STREAMLINED SEWAGE TREATMENT

Sewage treatment is falling in line with the spirit of the age—speed, streamlining, smooth operation, and attractive appearance. The contrast of the old steam locomotive and the sleek streamliner is no greater than that of a modern activated sludge plant, with speedy treatment and odorless sludge disposal, and the oldfashioned septic tank, with its long settling period, incomplete treatment, foul odors, and interminable sludge storage. All development in sewage treatment has been in the direction of acceleration of clarification, of aeration, of filtration and of sludge disposal. Sewage is now hurried through the plant, solids are snatched from the overlying liquid, sludge flashes through a dryer and incinerator and soon nothing is left but a limpid effluent and ashes.

The streamlining influence starts with screens. Formerly fecal, nauseating screenings were raked by hand to a channel and allowed to remain there exposed to the air, breeding flies and attracting adverse comments from visitors. Now screenings are raked mechanically, ground and discharged back into the sewage, or else a comminutor works continuously below the water surface, grinding the screenings and permitting them to continue unseen with the sewage in its streamline course.

Settling tanks are now being designed far more carefully than heretofore, with reference to inlet and outlet weirs, efficient utilization of settling chambers, and rapid removal of sludge. Primarily because of these technical improvements, smaller tanks and shorter settling periods are satisfactory. Solids are eased out of the tanks by rakes, suction orifices, or scrapers before the sludge has time to become septic, thus preventing odors and sour sludge.

Activated sludge treatment shows unmistakable trends toward shorter aeration periods, speedier rates of settling and decreased cost of operation. A battery of tanks at the Chicago North Side Treatment Works has operated for nearly two years with 3.2 hours of aeration, producing an effluent only slightly inferior to that from an adjoining battery with 5.0 hours of aeration. At Birmingham, England, bioflocculation of 1 hour duration has been used for years, although considered only as partial treatment. Research on activated sludge everywhere seeks to develop sludge or operating procedures which will shorten the time of aeration and thus increase the speed of treatment.

It remains for trickling filters, however, to represent the radical or leftist branch of streamlining in sewage treatment. It is a surprise to see what is trying to be done with the stodgy, reliable trickling filter. It is being pushed from the traditional rate of 3 million gallons per acre per day up to 10, 20—yes 40 m.g.a.d., and some enthusiasts claim

there is no deterioration in results. However, these men of vision may be willing to moderate their enthusiasm after some years of large-scale operating data are available. At present the BIO filter is the CIO of the sewage treatment field.

Chemical precipitation and mechanical filters are truly streamlined processes because the time of treatment is reduced to a minimum and the effluent slips through a ribbon of sand or magnetite in a few seconds.

Sludge disposal has gone streamlined with a vengeance. Digestion periods have grown shorter and shorter (although sometimes foam has grown longer and longer) and temperatures have risen to feverish ranges. However, substantial and trustworthy advances have been definitely established in shortening the period of sludge digestion.

Other developments of accelerated sludge disposal have included the abandonment of digestion entirely, and have comprised the filtration of sludge on high-production vacuum filters, with subsequent drying in "flash" dryers and final incineration in a blast of hot air. Drying in such "flash" dryers is a matter of seconds instead of minutes or hours (or days on open-air sludge beds). No better example of the modernization and streamlining of sludge disposal can be imagined.

All of this quest for speed is desirable, and no regrets need be expressed for the passing of the old horse-and-buggy days of sewage treatment. Present methods are more sanitary, more scientific and more salubrious than the procedures of the past decades, and so far there has not been any serious financial or technical wrecks caused by undue speed of development. A word of caution might be in order, however, namely, that standards of purification be not sacrificed in the race for speed and economy, and that we do not too complacently accept the promoters' or designers' promise of something just as good.

F. W. M.

HARRISON P. EDDY

It is hard to realize that Mr. Eddy is gone. He represented all that was finest and best as a man and as a sanitary engineer, and his friends will sorely miss his kindly greeting, his twinkling eye and his genial conversation. The engineering profession will miss his great technical knowledge, his distinguished service in its ranks, and his wise council in difficult problems. Sanitary engineers will look back to him even in coming generations, through his books, and the present generation of sanitary engineers and chemists will long remember the great personal ability and wise judgment he possessed in the field of sewage treatment. They will keep his memory as an inspiration, both personally and technically, throughout their lives.

F. W. M.

Proceedings of Local Associations

PENNSYLVANIA SEWAGE WORKS ASSOCIATION

Eleventh Annual Conference

State College, Pennsylvania, June 21, 22, 23, 1937

The Eleventh Annual Conference of the Pennsylvania Sewage Works Association was held at the Pennsylvania State College, June 21, 22, and 23, 1937. A total of 156 persons registered for the various sessions.

The annual golf tournament, which is held in cooperation with the Pennsylvania Water Works Operators Association, took place Wednesday afternoon, June 23rd, under the capable leadership of E. M. Jones. Mr. Jones headed the Golf Committee, which consisted of representatives of manufacturers and the two Associations. This committee presented 16 unusually attractive prizes, which were awarded the winners at the Thursday evening session of the Pennsylvania Water Works Operators Association.

As an added attraction this year, the two Associations sponsored a fishing trip under the leadership of Professor Pat O'Donnell of State College. which was open to members of both Associations. The Golf Committee also awarded prizes to the parties catching the largest and greatest number of trout.

The Annual Dinner, attended by 150, was held at the Nittany Lion Hotel Tuesday evening under the capable leadership of H. E. Moses, Assistant Chief Engineer of the Penna. Dept. of Health, whose humorous stories and introductions kept the group in a happy frame of mind for the entire evening.

The principal speaker at the Dinner was the Honorable Ellwood J. Turner, Vice-Chairman of the Interstate Commission on the Delaware River Basin, who reviewed the work being done by that Commission and outlined Legislation relating to sewerage matters passed by the recent Pennsylvania Session of Legislature.

Following Mr. Turner's address, Mr. Moses, with appropriate ceremony, instituted a new group in the Association to be known as the "Sludge Shoveler's Society." The first two members to be initiated were the Honorable E. J. Turner and Professor Pat O'Donnell of State College in recognition of their meritorious services to the Association.

At the Business Sessions of the Conference, the following officers were elected:

President	F. S. Friel
First Vice-President	C. F. Grace
Second Vice-President	G. M. Olewiler
Secretary-Treasurer	L. D. Matter
Editor	J. R. Hoffert
Representatives on Board of Control	C. A. Emerson, Jr., H. E. Moses

Mr. H. E. Moses, Secretary-Treasurer of the Federation of Sewage Works Associations, reviewed the progress of the Federation, commented upon the recently adopted changes in the Federation's Constitution and By-Laws and reported upon the progress being made in the preparation of a "Tenth Anniversary Volume" which, in effect, will be a manual of sewage works practice in the United Sates.

In addition to the customary resolutions of thanks to State College, the speakers, etc., the Association adopted a resolution of regret on the untimely passing of Harrison P. Eddy of Boston.

The Licensing Committee was continued for another year with authority to further study the question of licensing operators with the idea that a bill might be prepared for submission at the 1938 Conference for approval by the Association, which could be presented to the next session of the legislature.

The Correspondence Course Committee reported progress and requested further time to study ways and means of setting up a correspondence course for sewage treatment plant operators.

Upon receipt of a request that the Association endorse the Barkley-Vinson Bill (S-702-H. R. 2711), the matter was thrown open for discussion at the Business Session, at the conclusion of which the Executive Committee was instructed to study this and other Federal Legislation and to act in the name of the Association.

Because of the increase in interest in industrial waste treatment processes, the Executive Committee was authorized to consider the advisability of scheduling a limited number of papers concerning industrial wastes at future conferences.

The technical meetings produced many papers of high standard, as well as spirited discussion on controversial points. Professor L. V. Carpenter of New York University opened the meeting Monday evening with a blackboard talk on plant operation which was highly interesting.

The "Sewage Works Clinic" finished its second year with complete success under the leadership of H. M. Freeburn, District Engineer of the Penna. Dept. of Health. The entire afternoon of Tuesday, June 22, was devoted to this session, which was enlivened by considerable informal discussion.

The Tuesday and Wednesday morning sessions were devoted to the following major papers, some of which will appear in SEWAGE WORKS JOURNAL:

"Starting and Operating the Coatesville, Pa., Sewage Treatment Works."
"Effect of Industrial Waste on Sewage Treatment Plant Operation."
"Activated Carbon—Its Place in Sewage Treatment."
"Bio-Flocculation of Sewage."
"Aspects of Sewage Chlorination in 1937."

Several weeks prior to the Conference, it was decided to stage a gadget contest and the members were requested to exhibit their pet devices. Eight gadgets were exhibited which showing was encouraging considering the short time available for preparation. Prizes were awarded the exhibitors of the three outstanding gadgets. It is hoped to conduct another gadget contest in the near future, in which case the members will be given more time for preparation.

L. D. Matter,
Secretary-Treasurer

MICHIGAN SEWAGE WORKS ASSOCIATION

Twelfth Annual Meeting

Michigan State College, March 29–April 2, 1937

The Twelfth Annual Meeting of the Michigan Sewage Works Association was held at Michigan State College, March 29 to April 2, 1937. Following the general procedure of previous years the first half of the week was devoted to instruction in laboratory procedure and in plant operation and the last half to papers and discussions pertaining to sewage treatment. Enrollment in the school was 49 and total registration 112, the largest meeting in the history of the organization.

Following a welcoming speech by J. A. Hannah, Secretary of the State Board of Agriculture, a paper on the design and preliminary results of operation of the new activated sludge plant at Jackson was given by A. B. Cameron, Superintendent of the Jackson plant. Mr. Cameron is a new member of the Michigan group and his initial appearance was highly successful.

An innovation in the meeting this year was the group conferences held during an afternoon session. The procedure followed was to offer a choice of any one of four groups. The groups so arranged then conducted discussions among themselves of their particular subject. The chairmen of the individual groups then reported the highlights of the discussions in his group to the entire conference at an evening meeting. The consensus seemed to favor continuance of this part of the program in coming years with a further recommendation that more advance notice be given of the groups to be offered.

Professor Frank R. Theroux gave a brief talk to the conference on

the results which had been obtained in the operation of a small experimental plant treating sewage by ozone. Results obtained were very interesting and indicated further work along this line might well be conducted.

The association was very fortunate in securing C. C. Ruchhoft, Principal Chemist, U. S. Public Health Service, to give a paper on the biochemical oxygen demand test and oxidation in sewage treatment. The paper was exceedingly interesting and instructive and provoked a lively discussion.

L. F. Oeming of the Michigan Stream Control Commission gave a paper on industrial wastes and their effects on municipal sewage treatment plants. Mr. Oeming pointed out to the operators the characteristics of various trade wastes, their strength, and the manner in which they may affect individual plants.

N. G. Damoose, Superintendent of the Battle Creek sewage treatment plant, gave a very interesting description of the first year's operating experiences at Battle Creek. Particularly interesting was his description of the difficulties caused by the discharge of enormous volumes of grain into the sewers.

A discussion of the application of safety appliances in sewage plant operation was given by H. N. Gruber of the Mine Safety Appliance Company. Mr. Gruber indicated to the operators where to look for dangerous conditions, what they were, and the proper procedure to follow to remedy them.

Mr. F. H. Whitley of Chicago gave an interesting paper on the results of research work at the University of Illinois on the disposal of garbage with sewage. The paper was highly instructive indicating what success might be expected along this line. A very spirited discussion followed the presentation of this paper, indicating the great general interest in the subject.

Another new departure for the Michigan association was the "gadget" contest. First prize was awarded to Mr. Greene of Jackson, second prize to Mr. Ray and Mr. Wolohan of Dearborn, and third prize to Mr. Smith of Alma. A good deal of interest was displayed in the the contest and requests for continuation of the competition for another year was general.

At the annual business meeting R. A. Anderson was elected President; Thomas Doyle, Vice-president; Dr. W. L. Mallmann, Director for 1937–1938; and L. F. Oeming to fill unexpired term of Vincent Madison. W. F. Shephard was elected Secretary-Treasurer for the ensuing year. H. A. Olsen and James R. Rumsey were reappointed as Representatives on the Board of Control of the Federation of Sewage Works Associations.

W. F. Shephard,
Secretary-Treasurer

CALIFORNIA SEWAGE WORKS ASSOCIATION

Ninth Annual Conference

Stockton, California, April 23–24, 1937

The Ninth Annual Conference of the California Sewage Works Association, was held in Stockton, California, April 22–24, 1937. There were 163 members and guests registered, which established a "new high" in attendance for this Association. Much of the success of this meeting can be attributed to the local committee on arrangements, consisting of Wm. Ingram, *Chairman,* Lyle Payton, Fred West, Fred Post and Kenneth Brown, and to the Stockton Chamber of Commerce Convention Bureau.

A feature of this meeting was a special program for the ladies, which was well attended and which consisted of a tour to points of interest, culminating in an afternoon tea at the Haggin Memorial Gallery Museum. The wives of the local arrangement committee members made all arrangements for, and conducted the ladies program.

The morning of Friday, April 23rd, was given over to a tour of inspection. The members assembled at the Hotel Clark, Convention Headquarters, and from there, proceeded by caravan to the Lodi Activated Sludge Plant where much interesting work is being done on electrical metering. Clinton Henning, City Engineer of Lodi, from a point of vantage on the aeration tanks, explained the history and operation of the plant. The Stockton North Plant and South Plant were inspected in sequence. At these plants, revision was well under way, a detailed description of which may be found in a paper of last year (*This Journal,* **9**, 271, March, 1937) by Clyde C. Kennedy. For the first time, the caravan was without the guidance of the California State Motor Patrol. These officers, unfortunately, were all called to strike duty at Stockton Canneries.

A joint luncheon meeting, at which the attendance exceeded 200, was held with the Stockton Engineers Club at Hotel Clark. After an exchange of greetings between Vice-Mayor Woodrow Coale of Stockton and President Ed Reinke, Edward Hyatt, State Engineer, told of the difficulties surmonted in bringing the Central Valley Project to fruition. The first unit of this project will be under contract by fall; it will require $170,000,000 of State and Federal funds to complete, and will prevent the large agricultural area of the central valley from reverting to desert.

President Ed Reinke opened the technical session at 2:15 P.M. in the Walnut Room of the Hotel Clark. After a short discussion of the plants visited, during which members were privileged to ask questions of the operators and engineers in charge of the plants, Paul A. Shaw was called upon to present his paper "Stream Pollution of the Mokelumne River by Winery Wastes." In this paper, Mr. Shaw pointed out how industries can amicably be encouraged to remove detrimental wastes from streams, simply by presenting the actual facts to them.

The second speaker of the afternoon, Mr. S. I. Zack of the Filtration Equipment Company, New York, presented a paper on "Treatment of Effluents." This paper dealt largely with the magnetite filter, the purpose and operation of which was explained fully.

The "Symposium on Mechanical Equipment"; taken part in by the following operators, C. F. Tennant, J. H. Van Norman, R. C. White, H. M. Ely and F. W. Post with prepared papers and F. A. West and C. M. Hoskinson from notes, resulted in a short course in the choice of and installation of treatment plant equipment for the designing engineers.

The City of Stockton was host to the Association for a dinner meeting, the attendance at which numbered 152. Mayor Ralph W. Fay expressed his regret at not being able to welcome the Association officially at the noon meeting, but stated his desire to confirm the welcome extended by the Vice-Mayor. The report of the Committee on Award was read by Chairman Hommon and the bronze plaque presented to San Bernardino; Mr. Baird Livingston accepted the plaque and expressed his appreciation and that of his colleagues.

The speaker of the evening, Mr. Earl Lee Kelly, Director of Public Works, in speaking of the great bridge and fine highways of the State, paid tribute to the engineers, who by accomplishing unprecedented feat of construction, have made them possible. President Ed Reinke as Toastmaster, turned out a perfect evening.

The Saturday morning, April 24th, business meeting was very short, consisting principally of a report of the Committee on Certification and Schools, by Chairman Gordez and a report of the New York meeting of the Federation by Harold F. Gray.

Three papers were then presented. The first by J. H. Kimball and T. R. Gregory on "Cannery Wastes at Palo Alto" outlined the operation difficulties of a small plant subject to seasonal concentrated cannery wastes. The second by Carl E. Green on "Sewage Disposal in the Pacific Northwest," was a history of sewage treatment in Washington and Oregon, where strong sulphite wastes must be taken care of. The last paper by "Admiral" R. F. Brown, entitled "A Trip Through the Los Angeles Outfall Sewer," was so well told and illustrated by slides, that there is no longer any mystery about the condition of this outfall sewer.

R. R. Ribal,
Secretary-Treasurer

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Annual Spring Meeting

Utica, N. Y., June 3–5, 1937

The New York State Sewage Works Association held its Spring Meeting at Hotel Martin, Utica, N. Y., June 3, 4 and 5, 1937, President Charles C. Agar presiding. One hundred and sixty-five members and guests, including 24 ladies, were registered. The exhibits of 27 manu-

facturers were instructively displayed in very attractive booths on the mezzanine floor of the hotel.

Following registration and inspection of manufacturers' exhibits Thursday evening and Friday morning, the convention opened with a brief business meeting followed by the presentation of two papers Friday morning.

Frank N. Thomson, District Sanitary Engineer of the New York State Department of Health of Utica, discussed the status of sewerage and sewage treatment in the Utica area, outlining the advances made and under way in remedying the stream pollution problem. Professor William L. Malcolm, Queens University, Kingston, Ontario, gave a resumé of the paper he presented at the New York City meeting in January on "Studies in Digestion of Garbage." The discussion of his paper was opened by Morris M. Cohn of Schenectady followed by a written discussion prepared by Willem Rudolfs of New Brunswick, N. J., and further general discussion.

At the luncheon the Hon. Vincent R. Corrou, Mayor of the City of Utica, cordially welcomed the Convention to Utica. The Rating Committee Award, in the form of an engraved silver loving cup, was presented to Herbert O. Johnson of the Belgrave Sewer District by A. F. Dappert, Chairman of the Rating Committee. This award is presented annually to the operator who submits the report receiving the highest rating.

Three papers were presented at the afternoon session, one on "Variable Speed Equipment and Control in Sewage Treatment," by H. B. Diehl, Reeves Pulley Company, discussion of which was opened by M. B. Tark of the Link Belt Company. Lawrence Luther of Freeport, L. I., presented a paper on the "Origin, Organization and Value of the Long Island Section of the N.Y.S.S.W.A.," which aroused considerable interest among those contemplating the establishment of local sections in the State.

Henry Ryon, Senior Sanitary Engineer of the State Department of Public Works, and George D. Rounds, Chief Engineer of Marcy State Hospital, presented a joint paper and discussion of "Operating Difficulties and Enlargement of the Sewage Treatment Works at Marcy State Hospital."

Friday noon the ladies enjoyed an excellent luncheon and tour of inspection through the Baker Greenhouses and the Proctor Memorial Museum, where in addition to viewing the art treasures they were afforded an organ recital. The Friday evening banquet was followed by entertainment and floor show, and dancing until midnight.

Saturday morning, following the usual sunrise breakfast and question box, an innovation in the form of "Peddlers' Patter" proved to be very helpful. This period was devoted to brief statements by the representatives of the manufacturing exhibitors describing their products and answering numerous questions that had arisen during the display of exhibits.

At noon the motor cavalcade started for the Marcy State Hospital a

short distance outside the city where, through the courtesy of the hospital superintendent, luncheon was served to the group and the ladies were taken on tour of inspection through the hospital. The men visited the sewage treatment plant of the institution and observed the demonstration of a screenings grinder set up by the Chain Belt Company. Following this the cavalcade proceeded to the village of Herkimer and inspected the new municipal wastes disposal plant, which consists of a garbage and rubbish incinerator and a sewage treatment plant of the separate sludge digestion type.

The next meeting of the association will be held at Elmira, October 15 and 16, 1937.

The following had exhibits at the meeting:

Inertol Company
Wallace & Tiernan Company
Robinson Clay Products Co.
The Jeffrey Manufacturing Co.
Pacific Flush Tank Company
Flexible Sewer-Rod Equipment Co.
W. & L. E. Gurley
Royer Foundry & Machine Co.
Reeves Pulley Co. of N. Y., Inc.
Lord & Burnham Company
Wailes Dove-Hermiston Corp.
Link Belt Company
Nichols Engineering & Research Corp.
R. B. Carter Company
Industrial Chemical Sales Div., W. Virginia Pulp & Paper Co.
Chicago Pump Company
The International Nickle Co., Inc.
General Electric Company
American Brass Company
Trohn's Supplies, Inc.
The American Well Works
Johns-Manville Sales Corp.
Chain Belt Company
Will Corporation
Turbine Sewer Machine Sales Co.
Pittsburg Equitable Meter Co.
The Pardee Engineering Co.

Also the following journals: *Water Works and Sewerage, Municipal Sanitation, American City.*

A. S. Bedell,
Secretary

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION

Eleventh Annual Conference

Wilmington, Del., May 6 and 7, 1937

The Eleventh Annual Conference of the Maryland-Delaware Water and Sewerage Association was held in the Darling Hotel, Wilmington, Delaware, on May 6 and 7, 1937. There was a total registration of 127.

The Conference was opened by an address of welcome by Mr. A. W. James, President of the City Council of Wilmington. Mr. Francis S. Friel, Consulting Engineer, then presented a paper entitled "The City of Dover Combined Sewage Treatment Plant and Incinerator." The

plant was constructed as a P.W.A. project and placed in operation July 24, 1936. The plant consists of mechanically cleaned grit and screen chambers; pumping station; duplicate settling tanks equipped with straight-line sludge collectors; separate sludge digestion tank with floating cover and provisions for sludge heating; glass covered sludge bed, chlorination and chemical treatment equipment. The pumping station, laboratory and incinerator are all housed in one structure.

"Water Supply and Sewerage in Delaware" was the subject of a paper by Mr. R. C. Beckett, State Sanitary Engineer of Delaware. A statistical analysis indicated that 67 per cent of the State's population is accessible to public or privately owned water supply systems and 60 per cent have sewerage facilities available.

Two papers were next presented on water supply and one on floods.

"The Effect of Distillery Waste on the Westminster Sewage Treatment Plant" was presented by A. W. Blohm as the last paper of the first day. The sudden discharge of distillery waste into the public sewerage system resulted in foaming in the digester and completely upsetting of the operation of the entire plant. A period of five months was required to restore the plant to normal operation.

At the business meeting the following were elected officers for the ensuing year:

President: Edward S. Hopkins, Baltimore, Md.
First Vice-President: C. J. Bruce, Cumberland, Md.
Second Vice-President: A. M. Tawney, Fort George G. Meade, Md.
Secretary-Treasurer: A. W. Blohm, Baltimore, Md.
Elected to Executive Committee: J. M. Jester, Hyattsville, Md., four year term. W. N. Spring, Salisbury, Md., one year term.

The evening was devoted to a banquet, floor show and dancing with his Excellancy Richard C. McMullan, Governor of Delaware, as the principal speaker.

The second day started with three papers on water purification.

Col. W. A. Danielson, Chairman of the Committee on Research, American Society of Heating and Ventilating Engineers, closed the morning session of the second day with "Air Conditioning and its Relation to Public Water Supplies." Extensive use of air conditioning through public demand and as a preventive health measure was predicted. Water works engineers should make due allowances in the waterworks system to provide for increased air conditioning installations (and sewage works engineers for the increased volume of sewage, *Editor*).

Mr. Harry A. Faber read the paper "Chemical Precipitation and the Hagerstown Sewage Treatment Plant" which was prepared by H. W. Rhodes, Hagerstown, Md. Because of the advantage of duplicate units throughout the plant, parallel tests were run checking chemical precipitation against the activated sludge method of sewage treatment.

"The Formation of The Interstate Commission on the Delaware

River Basin'' was described by David W. Robinson, Acting Secretary of the Commission.

The Conference concluded with a ''Gadget Contest'' which was open to Active Members of the Association. The first prize of $10.00 was awarded to A. M. Tawney, Fort George G. Meade, Md., for a water heater for preheating the water used in chlorinators, and for a chlorine filter. A second prize was a one year's subscription to Water Works and Sewerage and was given by Linn H. Enslow, Editor. It was awarded to A. A. Bailey, Montebello Filtration Plant, Baltimore, Maryland, for an automatic priming valve and a water sampling device. Honorable mention was given to H. R. Hancock, Dover, Delaware, for a sludge depth indicator for sludge digestion tanks and a sludge sampler.

A trip to the Du Pont Gardens was enjoyed by the ladies.

A. W. Blohm,
Secretary-Treasurer

NORTHWESTERN OHIO SEWAGE CONFERENCE

Findlay, Ohio,
June 23, 1937

Mr. F. W. Mohlman, *Editor*,
Sewage Works Journal.
Dear Sir:

Relative to the recent organization of the ''Northwestern Ohio Sewage Conference,'' we enclose herewith a copy of the Constitution and By-laws and Report of the May Meeting, for your information and in fulfillment of the last sentence in Article III of the Constitution.*

We have postponed notifying the ''*Journal*'' until we had some assurance that the sectional conference would survive, and the attendance at the Delphos meeting last evening leads us to believe we are justified in saying that it is definitely a going concern.

Attendance at the organization meeting at Findlay on April 13th was 23 men from seven cities, at the first regular meeting in Bowling Green on May 18th—35, from the same towns and at Delphos on June 22nd, there were 38 present and two additional cities joined the conference.

Cities represented by Conference membership are: Bowling Green, Columbus Grove, Delphos, Findlay, Lima, Marion, Toledo, New Bremen and Van Wert, a total of nine out of the 18 sewage treatment plants in the 20 county areas. The 1937 officers are *Pres.*—Ben H. Barton, Findlay, *V. Pres.*—A. F. Redrup, Van Wert, and *Sec-Treas.*—A. H.

* III. Objects:
The objects of this society are to represent the body of Sewage Treatment Operators in all phases of the profession with a view of promoting the public interest as affected by the services of the Operator and safeguarding and strengthening the Association for this purpose; to advance the scientific, professional and economic interests of the Operator through research, promotion of technical and scientific information, legislation, care of public relations and maintenance of the integrity of professional practice; to cultivate fraternal feeling and cooperation among the members of the profession and to secure with them intelligent unity and harmony of action, and to cooperate with local, state and national sewage and wastes disposal organizations.

Niles, Toledo. Mr. Bruce M. McDill is an honorary member, representing the Dep't of Health of the State of Ohio.

Assuring you of our cooperation in any way we may serve we are

Northwestern Ohio Sewage Conference,

BEN H. BARTON, *President*,

207 Locust St.,

Findlay, Ohio

NORTHWESTERN OHIO SEWAGE CONFERENCE

Report of First Meeting

Bowling Green, Ohio, May 18, 1937

The first regular meeting of the Northwestern Ohio Sewage Conference, after the organization meeting at Findlay, Ohio, was held at the Bowling Green Plant. The members convened at 7:0 P.M. and an informal inspection of the plant was made.

At 8:30 P.M. the meeting was called to order and Mr. Barnes introduced Mayor Alva Bachman for an address of welcome to Bowling Green. He said, in part, "I am very happy, gentlemen, to have you over and look our plant over. We are very proud of this little plant, and hope that you will like it. It is not as extensive as, I suppose, some of the plants you have in your own localities, but at least we are proud of it, and I think all the citizens have been sold on the plant." Mayor Bachman extended warm congratulations to the members for having organized the conference and prophesied there would be much good accomplished by their regular meetings; intimating that the things the present sewage treatment operators do and learn will serve as a guide to future operators' procedure and future plant design.

Service-Director, Mr. E. J. Bowers, also gave a short talk explaining that the appearance of the buildings and grounds of the plant, which was maintained by the operators in connection with their routine duties, was a means of selling the plant to the public and helped to sell the inside workings of the plant. He complimented the Conference for their attendance, refusing to take up time that might be put to better use. Both officials amused the gathering with original and pertinent anecdotes, particularly the Mayor's goat-jumping story.

The procedure was instituted of members wearing name tags for the purpose of getting better acquainted and rising to roll-call. Thirty-five members were in attendance compared to twenty-three at the organization meeting.

Service-Director Weger, of Delphos, Ohio, was called upon for a few remarks and expressed his interest in the Conference and assured the members of his support in what ever way possible; he stated their method at the Delphos plant was for him to ask "Jack" (Wahmhoff) to tell him what to tell him to do and then see to it that he did it and that this method has worked out fine so far.

It was agreed that all persons in attendance at each meeting should pay a registration fee of 25 cents to finance the nominal expenses of the Conference and when the treasury has sufficient balance to remit this fee to regular members.

A letter of congratulation on the Conference launching was read from Mr. C. K. Calvert, of Indianapolis, Indiana.

By unanimous action the name of the Organization was changed from The North Western Ohio Association of Sewage Treatment Operators to Northwestern Ohio Sewage Conference.

Mr. Britt presented questionnaires to the members on wage scales, duties, hours per shift, etc., and stated that summaries would be available upon application.

The question of mimeographed transcripts of the proceedings of each meeting was decided favorably by unanimous vote and committees appointed for the purpose of ascertaining the best manner and means of preparing the transcripts for the membership and subscriptions if requested. It was suggested that the final or annual number contain a roster of the membership.

Mr. Blosser, of Columbus Grove, arranged for Delphos to take the June meeting date, the 22nd, because his technical supervisor and designer of the plant could not be present at the June meeting.

The President discussed industrial wastes and sewage plant operation, with respect to industry's attitude and the possible procedure of the operator in such cases. On October 9, 1936, Mr. Roy L. Johnson of Fairfax, Minn., and on May 15th, Mr. L. A. Koritz of Rochelle, Ill., called upon The Findlay Sewage Treatment Plant for information relative to the treatment of corn and pea canning wastes. In both cases the men represented associations or canning syndicates and apparently were seeking a means of economically disposing of the wastes of their companies. As this type of industry is located in the smaller agriculture centers with sewage plants designed on population basis and their waste is several times that of the municipality's, it develops that waste treatment structures at the canneries would cost more than the total investment in the cannery proper, thus presenting a very serious problem.

The logical procedure would be to devise ways and means for the industry to modify its wastes to a point where they are acceptable to the sewage plant or stream disposal. This modification appears to be a function of the sewage treatment plant operator, in so far as he is recompensed to some degree for his efforts and measure of success. This matter is best attacked in sewage conference meetings to provide the interchange of experience and ideas, which would not be available to individual municipality officials, and the discussion would smooth out possible procedure technique. The burning of dried corn-wastes at Battle Creek, Michigan, and Bowling Green difficulties with Heinz tomato and pickle wastes was mentioned to Mr. Koritz. He was particularly pleased to hear of the Battle Creek solution of Kellog and Post factory disposal wastes by Mr. Damoose who discovered by accident, that it would burn readily after drying in open sludge lagoons, without adding fuel. However waste from pea canning will require pretreatment before admitting to the sewer system according to the data on hand from the above men's experiences.

The Conference, by unanimous vote, elected Mr. Bruce McDill, Ass't Eng. of the Dep't. of Health, State of Ohio, as an honorary member in the Conference. Mr. McDill pays the most visits in the area covered by the Conference membership, and the members wished to pay the Dep't tribute by the above action.

Mr. C. E. Britt, in charge of laboratory work in the Bowling Green Plant discussed plant efficiency with respect to normal domestic sewage flow determinations compared with the analyses during the period of maximum industrial-waste flow from the Heinz factories during September. The data are as follows:

Suspended Solids, Year 1936

	Raw Sewage	Primary Effluent	Filtered Effluent	Final Effluent	Per Cent Reduction
Maximum	300	124	90	35	97.6
Minimum	61	31	8	2	61.3*
Average	191	70	35	13	90.3
September	225	86	37	14	93.9

Dissolved Oxygen, 1936

	Raw Sewage	Final Effluent
Maximum	8.6	11.3
Minimum	0.2	3.5
Average	3.3	6.3
September	0.2	3.5

Bio-Chemical Oxygen Demand, 1936

	Raw Sewage	Primary Effluent	Final Effluent	Per Cent Reduction
Maximum	591	447	111	90.3
Minimum	75	44	12	31.6
Average	232	149	33	82.2
September	591	447	111	81.2

Figures other than per cents are in parts per million.
* February 1936, Primary treatment only due to frozen filters.

Mr. A. H. Niles gave a very complete and extremely interesting paper on the Bowling Green plant design and the operating conditions to be met and how these conditions were worked out in the plant structure successfully. He further discussed the future additions necessary for the inclusion of the Heinz Company's expansion of factory wastes, as follows:

Bowling Green has a combined system of sewers. The intereceptor starts from the combined junction and diversion chamber at the end of the 78 in. Poe Road sewer, some 2,200 feet from the treatment plant. The flow from the Bowling Green State University sewer enters the plant at the end of the interceptor and just ahead of the bar screen. There is an automatic overflow and bypass from this point to Poe Ditch, so that, in case of power failure, the plant is automatically by-passed. The bar screen is of the conventional type and is hand raked.

There are two grit chambers with "Sutro" or proportional weirs so that the velocity through the grit chambers is held to approximately one foot per second, regardless of flow. The sewage pumps are of the horizontal centrifugal type; 1–500 g.p.m. and 2–750 g.p.m., with provision for the installation of another one, probably 1,000 to 1,250 g.p.m. capacity. A Bailey meter is installed in the pump discharge line to measure the flow. flow.

There are two primary settling tanks at present, each 14 ft. wide, 60 ft. long and 10 ft. side water depth. These tanks are attached to the main building and equipped with Link Belt sludge collecting mechanisms, as is also the final tank. The sludge pumps are Barnes-Dorrco, located in the basement of the main building with a very short run of piping to the primary sludge pumps. Provision is made for adding a third tank on the west side of the present ones.

The filters are two in number, each 118 ft. in diameter by 7½ ft. filter media depth above the underdrainage system, which is Armcore block. The filter stone is local limestone for the lower 6 feet. Sodium sulphate accelerated weathering tests were run on this stone, and it was finally decided that it would be satisfactory for the lower portion of the filters, but not sound enough for the surfacing material. Blast furnace slag was used for the upper 18 inches of the filters and the wisdom of using this material where severe weathering usually takes place, has already been demonstrated. During the severe winter of 1934–35 when surface stone on many trickling filters in Ohio and the midwest disintegrated so badly the whole of the filter material had to be removed, no trouble whatever was experienced with disintegration of the slag or of the underlying limestone. American Well Works motor driven distributors were used instead of hydraulically operated ones on account of the low loss of head which they permit between the primary tanks and the filter surface.

One final tank 16 ft. wide by 50 ft. long by 7 ft. side water depth prevents the filters from unloading directly into Poe Ditch when sloughing. The final effluent trough is lined with white hexagonal tile to show the public the clarity of the final effluent from the plant. Provision is made for the addition of one more final tank and at least two more filters of the same size as the present ones.

The digester, 45 ft. in diameter by 19 ft. side water depth, is of the fixed cover type with Dorr stirring mechanism and is heated by hot water coils and a gas fired hot water

boiler located in the basement of the main building. The building is heated by a hot water coal fired boiler cross connected with the gas fired boiler so that either digester or building may be heated from either boiler or used in parallel.

Sludge is dried in a glass covered drying bed 40 ft. by 135 ft., divided into 6 sections. A monorail system with one yard dump bucket is used to convey sludge from the beds and by an extension of the same system, is used to remove grit from the grit chambers.

A Wallace & Tiernan chlorinator provides for chlorination at three points, viz. the wet wall, the primary tank and the secondary tank. Prechlorination has been practiced very effectually for the control of odors. Odors are watched very carefully on account of the relative close proximity of the College. A garage and shop building completes the picture as far as buildings and structures are concerned.

In order to care for the H. J. Heinz ketchup plant, which has a waste during the peak of their season of at least 4 times the volume and twice the strength of Bowling Green's domestic sewage at present, 1 more pump, 1 additional primary and secondary settling tank each, 2 more filters of the same size as the present ones, and an additional digester, has been planned. This addition should enable the Bowling Green Sewage Treatment works to turn out a uniformly good effluent during the Heinz season, as well as during the rest of the year.

The July meeting will be at Columbus Grove on the 20th, with Mr. Floyd G. Brown, designer and technical-supervisor, giving a description and discussion of the plant.

Reviews and Abstracts

H. W. Streeter

GAS COLLECTION IN SEWAGE TREATMENT PLANTS

By H. Keppner

Gesundh.-Ing., 59, 166, 1936

At Munich, the dry weather flow of about 90 to 105 cu. ft. per second first passes through coarse screens and grit chambers and then through 32 large settling tanks, 82 ft. long, in which the velocity is 0.2 in. per second. About 84 per cent of the settleable solids automatically pass into the digestion chambers which lie below the settling tank. The digestion tanks have a total capacity of 1.86 cu. ft. per capita or 1.2 cu. ft. per capita below the slots. About 2 per cent of the sewage flows through the digestion chambers and this small amount of septic sewage flows to a special tank where the sludge particles are removed by sedimentation and digested to form gas.

In 1929–30 the digestion tanks were equipped for gas collection and the gas from each unit is measured by small gas meters. The entire amount is measured by a large meter. The gas passes to a compressor and then to the municipal gas works which are about six miles away. The gas from the sewage treatment plant furnishes about 8 per cent of the needs of the city.

The amount of gas produced annually since 1931 varied from 115.75 to 125 million cu. ft. and the heat value of the gas varied from 293 to 320 B.T.U. per capita per day. The amount of solids per capita per day from which gas was obtained was 24 grams in 1931–32, 12 grams in 1932–33 and 17 grams in 1933–34. The suspended organic solids removed from the sewage varied from 17.4 to 20.4 grams per capita per day. In previous years this value has reached 27.2 grams so that 18.5 to 27.2 grams of organic solids are necessary to produce 310 B.T.U. or 0.24 cu. ft. of gas in the digestion chambers since on an average one cubic foot of gas has a heat value of 740 B.T.U. About 43.5 to 63.8 per cent of the organic matter is consumed. Part of the remainder of the suspended organic solids is liquified and part is included in the digested sludge.

About 9 per cent of the Munich sewage consists of wash water from the breweries. The relatively small amount of concentrated brewery waste reaching the plant contains yeast and barley. As most of the barley is found unchanged in the scum, it is not important in the production of gas.

G. P. Edwards

PRELIMINARY GUIDES FOR THE DESIGN OF SETTLING TANKS

By Dr. Ing. W. Merkel

Gesundh.-Ing., 59, 51, 1936

The present method for designing settling tanks depends on the use of the Imhoff cone and assumes a uniform velocity over the entire tank cross section. The length of tanks now used varies widely and, although the importance of proper design of inlets and outlets is recognized, many types are chosen and the design of some contradicts the principles employed in others.

Experiments show that the efficiency of settling tanks usually varies between 10 and 40 per cent and only rarely reaches 50 to 60 per cent. The detention period is considerably shorter than assumed in the calculations and if clarification is satisfactory, either the tank is larger than necessary or the method of calculation wrong.

Besides the particle size and the specific gravity, which affect the settling velocity of a particle, the structure, that is, whether it is granular or flocculent, lyophilic or lyophobic, is also important. Granular lyophobic particles are seldom obtained, as even sand, after standing in sewage, becomes coated with an organic film and the usual laws governing the settling of pure sand can be applied in municipal sewage only to a limited extent. The effect of temperature on the viscosity of water and the settling velocity of a particle is also important.

The efficiency of a settling tank depends more on its shape than its size. Baffles aid in preventing short circuiting but uniform distribution over the tank is best obtained through proper design of the inlet and outlet. With flocculent solids of low settling velocity, vertical or radial flow tanks are more economical. Best clarification is obtained by making the bottom of tanks smaller than the top.

In general, tanks are designed so that the smallest particle to be retained settles so far before reaching the outlet that it is not carried over the effluent weir. It need not reach the bottom. At the inlet and outlet, the sewage must enter and be withdrawn uniformly over the entire width of the tank. The inlet should be at the surface and the liquid should have a velocity of 2.75 to 4 in. per second. The skimming baffle should not extend into the water more than 1.2 to 2 inches and should therefore be adjustable for changing water levels. In horizontal flow tanks the sewage should flow along the surface as much as possible and, since the efficiency of settling tanks is only 30 per cent, the velocity at the surface may possibly be two or three times the value now assumed as an average.

The measurements of the tank may be best expressed in terms of gallons per second per foot width. With a sewage of average strength and a load of .8 to 1.2 gal. per second per ft. width, a length of 100 to 115 ft. is desirable and for loads of 1.2 to 1.6 gal. per sec. per ft. width a length of 130 ft. is sufficient. In hopper bottomed tanks, such as Imhoff tanks, the length can probably be 15 to 20 per cent less. If preliminary experiments indicate that a tank length of 100 to 130 ft. is insufficient even with a smaller load, vertical flow tanks are more economical. A depth of 6.5 to 7.5 ft. is satisfactory for a load of 0.8 to 1.2 gal. per sec. per ft. width of tank and depths of more than 10 ft. are to be avoided. In a tank with a rectangular cross section, the width should be 1/4 to 1/5 of the length and in hopper bottomed tanks, the width may be as much as 1/8 of the length.

G. P. Edwards

SLUDGE INCINERATION

By Dr. Ing. Karl Imhoff

Gesundh.-Ing., **59**, No. 40, 1936

After many years of experimentation, sludge is being incinerated at the Dearborn sewage treatment plant, which has a connected population of 200,000 and at the Chicago Calumet plant serving a population of 300,000.

Three incinerating processes have been used in Germany. In the Degener process (1898–1914), about 13 to 17 lb. of ground brown coal was mixed with 1,000 gal. of sewage and the mixture coagulated with the aid of 2.5 to 3 lb. of aluminum and iron sulphate. After two hours sedimentation, the sludge was dewatered in a filter press and then burned. Although the results were satisfactory, the cost was so high that operation was discontinued. In Frankfurt a. M. fresh sewage solids were dewatered in a centrifuge and further dried in a drum type drier before incineration. High cost of operation during the war also forced this plant to close down. From 1926 to 1929 experiments were carried on in Essen by the Emschergenossenschaft and plans were made to dry the sludge from the Essen-Karnap plant and burn it as a powdered fuel. The 250,000 tons of sludge received there annually consist principally of precipitated coal but it also included the sewage sludge from one million inhabitants. This sludge contained 45 per

cent ash on a dry basis and after storage it had about 50 per cent moisture. It was dried to a moisture content of 1.5 per cent in a drum type drier, powdered and burned. The plant is not in operation at the present time.

The first step in incineration is the artificial dewatering of the sludge. In the new American plants, vacuum filters are used and the sludge conditioned with ferric chloride. It is estimated that filters are more economical than drying beds for dewatering digested sludge of cities larger than 100,000 population. The question of whether fresh or digested sludge should be filtered is still under discussion. In general, sludge is first digested because the quantity is decreased and nuisance from odor is avoided. Chicago is an exception to this generalization. The new Calumet activated sludge plant receives a daily flow of about 340 gallons per capita connected. The incinerator was put into operation in May, 1936. Small tanks with a detention period of ten minutes are used instead of the customary preliminary settling tanks and the sludge is not digested. The grit and sludge from the small tanks, the ground screenings and the excess activated sludge, in all about 42 tons per day dry basis, are pumped to small concentrating tanks. The drying and incinerating plant consists of three independent units, making it adaptable to variations in the amount of sludge. Small variations in the daily amount of solids are equalized in the aeration tanks. About 4 to 6 per cent ferric chloride on a dry basis is added to the fresh solids in a mixing tank which has a detention period of ten minutes and uses a stirring apparatus with a peripheral velocity of about one foot per second. The sludge and ferric chloride are automatically measured with a weir and the correct dosage is controlled by an electrical device. The three Oliver filters have diameters of about 11.5 feet and an effective area of 560 feet. The filtering rate is about 3 pounds of dry solids per square foot per hour. Each filter handles daily 20 tons of sludge containing 97 per cent moisture and yields a cake containing 80 per cent or less moisture.

The filter cake is automatically weighed and mixed with enough dried sludge to reduce the moisture to 45 per cent. The mixture is pulverized and dried with superheated steam which has a temperature of 1000° F. The dried sludge, after separation from the steam, is blown into the incinerator where it is burned at a temperature of 2460° F. The consumption of powdered coal as fuel is very small.

At Dearborn, the digested sludge from the East Side plant and the fresh solids from the chemical precipitation plant at the West Side are all burned at the latter place. Paper pulp is no longer used and lime and ferric chloride are omitted when the sewage is thin. The magnetite filters which are attached to the periphery of the Dorr tanks have been satisfactory. The Dorr tanks are used for the concentration of the Imhoff sludge from the East Side plant. This sludge is now handled separately on the vacuum filters. According to the operating report of March, 1936, the B.O.D. of the sewage in the chemical precipitation plant is reduced from 93 to 41 or about 56 per cent and the suspended solids are reduced from 120 to 28, about 76 per cent. On a dry basis, about 8.5 per cent of the sludge is obtained from the chemical precipitation plant and 91.5 per cent from the East Side plant. The wet sludge has a moisture content of 89.3 per cent and the filter cake 66.3 per cent. The filter rate is about 4.3 lb. of dry sludge per sq. ft. per hour.

The incinerator which has a diameter of 13 ft. and a height of 16.5 ft. contains six shelves upon which the sludge is rotated mechanically. The sludge is added at the top, dried on the upper two shelves, burned on the two center shelves and the ash is cooled on the two lower ones. Oil burners placed on three shelves aid in burning the sludge. The air is preheated by the gases of combustion. The incinerator is maintained at a temperature of 1650° F. and the gases leave at about 1100° F.

According to the March, 1936, operating data, 1,010 tons of sludge containing 66.3 per cent moisture were burned in 504 hours or 21 days per month. The sludge contained 49.2 per cent combustible material on a dry basis. Oil as fuel was added only at the start of incineration and during operating difficulties. In March, 1936, 0.6 gallon of oil was used per ton of filter cake. About 3.5 k.w.h. were needed per ton of sludge for power. The ash contained only 1.5 per cent of organic matter. The initial cost of the incinerating plant, excluding the buildings, was $56,000. The annual costs are:

Interest	5.8%	$ 3,248.00
Amortization	4.2%	2,352.00
Maintenance	2.0%	1,120.00
Operation		8,495.00
		$15,215.00 or $1.26 per ton of sludge

The Chicago process is suitable for very large cities but the Nichols incinerator in Dearborn is so simple that it seems to be suitable for cities of medium size. Large digestion tanks or other facilities for storage permit the use of smaller incineration plants.

G. P. EDWARDS

SOME COMMON SENSE CONSIDERATIONS IN SEWAGE DISPOSAL

BY H. C. SHENTON

The Surveyor, **91**, 775–776 (June 4, 1937)

There is a very great difference between the knowledge of chemistry and bacteriology and a knowledge of sewage disposal, the latter requiring practical experience extending over many conditions and a knowledge of hydraulics, structural engineering and mechanical plant.

Since the settlement and disposal of the grosser solids can be accomplished easily, it seems logical, especially in smaller plants where the sewage is relatively fresh, to avoid such measures as disintegration of solids, long detention periods and conditions which tend to give septicity, since these facilitate the liquefaction of solid matters with a resultant greater burden on the final purification processes.

Experiments have shown that by gentle agitation of the effluent from the primary tanks a certain coagulation and settlement of material has been obtained and the B.O.D. of the settled effluent has also been reduced. Such flocculation is a very delicate process, however, and the best procedure can only be arrived at by trial with the full scale plant, making it essential that speed regulators should be provided for the floceulators.

There are many sources of odors in sewage treatment plants, but many works could be made practically odorless if more attention were given to covering the small channels through which the sewage flows in the preliminary stages of treatment.

More attention should be paid to the ultimate object of preventing a nuisance in the receiving stream rather than satisfying fixed requirements as to the treatment of any given proportion of the sewage during storm water flows.

R. W. KEHR

SEWAGE DISPOSAL. PROVISION FOR TREATMENT OF TRADE WASTES: SELECTION OF PROCESS AND PLANT DESIGN

BY JOHN HURLEY

The Surveyor, **91**, 695–696 (May 14, 1937)

Few factories have either the space or personnel to effectively purify their waste liquors, and the preliminary treatment given trade wastes should therefore be kept at a minimum and the problem passed on to the sewage works where a more adequate plant and better supervision are available.

Where trouble and expense are caused by the treatment of such wastes, an agreement should be entered into with the manufacturer whereby he makes a substantial contribution towards the cost. The agreement should cover, in general:

(1) The term of the contract.
(2) Provision for revision or arbitration at the end of the stated term if the discharge of wastes is continued.
(3) Necessary removal of grit and solid matter.
(4) Other preliminary treatment.
(5) Maximum temperature of wastes (generally 80°–150° F.).
(6) Approved plan to provide for delivery to the municipal sewers.
(7) Regulation of rate of flow.
(8) Access for inspectors to the manufacturer's works.
(9) Arrangements for assessing flows.
(10) Payments, powers of recovery of damages, provision for arbitration, etc.

In the design of plants for treating a sewage containing trade wastes, every effort should be made to prevent stagnation or short-circuiting in the primary sedimentation tanks. Well-designed tanks sludged by mechanical means give approximately as effective sedimentation in 6 hours as the older type of tank gives in 12 hours. The presence of difficult trade wastes, especially in varying concentration, favors the adoption of trickling filters as secondary treatment.

R. W. KEHR

WOLVERHAMPTON SEWAGE DISPOSAL WORKS

ANON

The Surveyor, **91**, 734 (May 21, 1937)

The Barnhurst works at Wolverhampton, designed for 5 m.g.d., treat an average dry weather flow of 6.4 m.g.d. of sewage containing 40 per cent trade waste, producing an effluent of 10.4 p.p.m. from filters and 11.1 p.p.m. from bio-aeration channels.

The sewage passes through mechanically raked screens, float-actuated, then through mechanically cleaned grit chambers to a lime mixer where milk of lime is added to neutralize rushes of acid wastes There are two mechanically scraped primary sedimentation tanks with six hours' detention, from which the sludge may either be pumped to digesters or to land for manurial purposes. Secondary treatment is provided by bio-aeration channels and trickling filters, which may be used in parallel or the entire flow may be treated in the bio-aeration channels, then passed through the trickling filters. The bio-aeration channels are arranged in 4 closed circuits, each 6 ft. wide and a mile long, with paddle agitation. Reactivation by diffused air is provided for the return sludge from one of two units. The trickling filters are 7 ft. 6 in. deep, with the bottom 6 in. of 1½ to 2 in. material and the top 7 ft. of ¾ in. material, a total volume of 63,000 cu. yds. Storm water is treated up to 3 times the dry weather flow, above which it flows to storm water tanks to be held and treated later except for unusual storms.

There are two sets of sludge digestion tanks, four at an upper level and four at a lower level, with a total capacity of 4.5 mg., or 6 cu. ft. per capita. The 6½ acres of sludge-drying beds are not in use at present, due to the demand from neighboring farmers for the liquid, undigested sludge. It is planned to install trickling filters to care for an additional 0.5 m.g.d.

R. W. KEHR

WEST LANCASHIRE RURAL DISTRICT SEWERAGE

ANON

The Surveyor, **91**, 555 (April 16, 1937)

The plant serving this district of 2,200 acres was designed for a population of 10,500 persons plus a flow of 25,000 gallons per day of trade wastes. Sewage enters the

disposal plant from a 24 in. outfall, is screened by time-operated, duplicate mechanical screens, which discharge screenings through a belt conveyor outside the building. The sewage is then pumped into a balancing tank and from there flows through a constant flow floating draw-off pipe at the dry weather flow rate to the settling tanks which provide 12 hours' sedimentation at that rate. Flows higher than the dry weather rate spill over a weir and also discharge to the sedimentation tanks. The balancing tank and settling tanks are built on piers 10-12 ft. above ground since the plant grounds are subject to flooding. There are four 91 ft. diameter by 6 ft. deep trickling filters of "Altacon" blast furnace coke, which are dosed at a rate of 50 gal. per cu. yd. per day. The sludge is pumped to a group of fifteen sludge beds consisting of 18 in. of graded clinker topped with ashes. Dewatered sludge is stored for further drying and use as a fertilizer by farmers. In constructing one of the sewers it was necessary to carry a 33 in. and a 15 in. sewer across a 50 ft. canal in 48 hours in order not to obstruct canal traffic. This was done by driving a cofferdam of sheet steel piling. In another such crossing it was possible to negotiate half the width at one time, leaving the other half of the canal open for traffic.

R. W. KEHR

SEWAGE DISPOSAL AT BUSHEY, HERTS

ANON

The Surveyor, **91**, 562 (April 16, 1937)

The original works, consisting of chemical precipitation and intermittent filtration on land, constructed in 1893, were remodeled in 1910 to include screening, sedimentation, percolating filtration through clinker filters, sedimentation of the trickling filter effluent and additional filtration through sand filters. Sedimentation was provided for storm water flows in excess of three times the dry weather flow. Recent extensions to the plant include three 85 ft. diameter trickling filters, a new humus tank and additional sand filters. Sludge is digested, dewatered on sludge drying beds, and after drying is removed and ploughed into the land. Recently chloride of lime has been successfully used to prevent ponding of the old clinker trickling filters.

R. W. KEHR

SEWAGE DISPOSAL AT BRADFORD

ANON

The Surveyor, **91**, 587 (April 23, 1937)

The reconstructed works at Bradford are designed to treat 4 m.g.d of sewage of about half domestic and half industrial origin. The plant includes detritus tanks from which the heavier mineral matter is removed from the inlet end by grab buckets while the lighter sludge near the outlet end flows to "sludge rams" from which it is forced by compressed air to the sludge storage tanks. The effluent from the sedimentation tanks is filtered through 5 ft. 6 in. of 1 to 2 in. coal in rectangular beds equipped with traveling distributors. Excess flows are treated in the old filters which have fixed nozzle sprays and consist of 6 ft. shale beds without masonry floors or walls. A detention period of 4 1/5 hours, dry weather flow, is provided in the humus tanks. All sludges, totaling 6,500 tons of 95 per cent sludge per year, are lifted by a 5-ton sludge ram from the sludge storage tanks to the filter press house, treated with 1½ to 2 per cent lime and pressed in 1 hour from 95 to 68 per cent moisture content, which upon storage in open air beds, reduces to about 34 per cent moisture.

R. W. KEHR

OBSERVATIONS ON SEWAGE FLIES. THEIR SEASONAL INCIDENCE AND ABUNDANCE

By L. L. Lloyd

The Surveyor, **91**, 465 (March 26, 1937)

In the United States attention is sometimes centered on *Psychoda* flies as a nuisance at sewage treatment plants, but other flies, including mosquitoes, are largely neglected. In this paper the author gives a careful study of the incidence and interrelationships of five flies common to filter beds.

The annoying heavy summer emergence of *Psychoda alternata* is said to be due to a lack of balance of the filter bed fauna, and the studies include an attempt to evaluate this balance so as to adjust it without interfering with filter bed operation, as by pooling. Trapping the emerging flies has given relative seasonal numbers at Knostrop (Leeds) for 3 years and at Barnsley for 2 years. *Psychoda alternata* and *P. severini* are present in quantity at Barnsley all the year, but most numerous from January to April, whereas they are practically absent at Knostrop except for summer and spring swarms. Data covers mating temperatures (males are practically unknown for *P. severini*) numbers of eggs laid, optimum breeding range, length of time required to complete the life cycle and feeding habits. *P. alternata* prefers the highest temperatures, 16–25° C., and has the quickest developmental cycle; these factors favor a heavy summer occurrence despite the low number of eggs laid per female (100 as against 200 or 450 for *Spaniotoma* or *Metriocnemus*) and the use of its eggs and larvae for food by the other four species.

Since the predatory species *Spaniotoma minima, Metriocnemus longitarsus* and *M. hirticollis* are shown to eat *P. alternata* eggs and larvae and since they increase rapidly at Knostrop in late summer and autumn, it is concluded that they are responsible for the early autumnal decrease there of *P. alternata*, while its greater abundance at Barnsley is partly due to their absence at that plant.

This work suggests the marked value of biological studies which might show how biological balances can be maintained and thereby eliminate objectionable dominant populations.

James B. Lackey

LABORATORY AND LARGE SCALE EXPERIMENTS ON THE PURIFICATION OF DAIRY WASTES

By S. H. Jenkins

The Surveyor, **91**, 463 (March 26, 1937). Discussion, *The Surveyor*, **91**, 605–607 (April 23, 1937)

About one-half billion gallons of milk are used annually in the manufacture of milk products and another half billion is consumed in liquid form.

In experiments at Rothamsted a 1 per cent milk solution was passed through a lath filter and the effluent treated successfully on a gravel filter. Mixtures containing 0.25 per cent milk were as difficult to treat by activated sludge as 5 per cent mixture (referred to later in the discussion as 0.5 per cent milk). While it was difficult to build up an activated sludge from milk solutions, activated sludge from domestic sewage produced a clear effluent after 1 day's aeration and retained its capacity for purification. The presence of lactic acid resulted in a better effluent. Milk wastes stored for 24 hours have most of the complex organic constituents broken up into simpler compounds with an apparent B.O.D. removal of 25 per cent. A 1 per cent milk solution so treated gave an effluent containing 32 p.p.m. of B.O.D. and had nitrates present when filtered at 100 gals./cu. yd./day through a gravel filter. Similar treatment without storage would have rapidly clogged the filter. These results were confirmed by experiments by

Messrs. Whitehead and O'Shaughnessy at Birmingham, who also showed that filters which had choked when treating sewage liquors could be cleaned by dosing with partially purified effluents. Preliminary experiments with milk wastes indicated that by using two filters in series and periodically altering the order of dosing, the major purification occurred in the first filter but both filters could be kept clean.

An experimental plant was constructed at Ellesmere to test this double filtration method in parallel with activated sludge. Milk washings were stored in an underground tank. The two filters each consisted of 4 ft. 3 in. of ¾ in. to 1¼ in. gravel. From laboratory data the filters were designed to treat 8,750 gals./day of milk wastes, equivalent to 2 per cent milk. Rates of application up to 25,000 g.p.d. of 0.25 per cent milk (wastes) have not exceeded the capacity of the filters. A three weeks' period is allowed between changing of the order of dosage of the filters, which keeps the filters clean. One or two days after changing the order of dosing the film on the secondary filter broke away and slowly disappeared. Using double filtration, the final effluent exceeded 20 p.p.m. B.O.D. in only 7 of 352 samples.

In treating the wastes with activated sludge, the optimum concentrations of sludge were between 20 and 50 per cent by volume after 30 minutes' settling. The tank was accidentally dosed with wastes of 1900 p.p.m. B.O.D. and required over 8 days to get back to normal from an effluent B.O.D. of 70 p.p.m. Better results were obtained using stronger wastes with less dilution but a correspondingly longer period of aeration. A waste of 350 p.p.m. could be reduced to 5.8 p.p.m. with 24 hours aeration period.

Discussion

Mr. H. C. Whitehead commented on the high rates of filtration obtained, 160 gallons per cubic yard, which gave better results than were normally obtained filtering sewage of similar strength at a 100-gallon rate with single filtration. To him, such results indicated considerable room for improvement in the standard methods of treating sewage.

Mr. W. H. Makepeace (Stoke on Trent) mentioned an experimental plant treating dairy wastes at Staffordshire, where odor difficulties were found to originate in the balancing tank. After eliminating as much wastage of milk as possible, good results were obtained by partial aeration, sedimentation and screening through straw mat screens. He felt the experiments were quite worth while, since no particular firm could afford to attack the problem of its waste disposal from a scientific point of view unless it had the backing of experiments such as those at Ellesmere.

Dr. A. Parker (Asst. Director of Water Pollution Research) remarked about the savings in the cost of milk waste treatment which could be accomplished by cutting down the amount of milk wasted. Usually losses amounted to less than 0.5 per cent at distributing and collecting depots, whereas processing plants might lose as much as 1 per cent in the waste waters. At Ellesmere, wastes had been cut from about 0.6 to 0.2 per cent with minor modifications such as returning the first small washings of buttermilk churns and cheese vats to the buttermilk or whey.

While they had originally anticipated a filtering rate of 80 gallons per cubic yard per day based on the volume of both filters, an effluent of less than 10 p.p.m. B.O.D. was produced at a 160-gallon rate, and rates of 240 gallons had been used. The excellent results obtained when treating wastes of 400–500 p.p.m. B.O.D. compared to those with 200–300 might, he thought, be influenced somewhat by the higher temperatures of the more concentrated wastes, and the conditions under which the experiments were made were therefore not directly comparable. While small volumes of dairy wastes could be advantageously treated with sewage, at certain plants where the proportions of dairy wastes were high, difficulties had arisen with the sewage treatment processes.

Dr. Parker concluded by commenting on the excellent cooperation of the dairy industry which had contributed over £9,000 toward the cost of the investigation and had at present under construction several treatment plants designed along the lines of the biological filtration plant at Ellesmere.

Mr. J. Hurley (Wolverhampton) thought it remarkable that working biological filters in series should make so much difference when they were recirculating the effluent.

He questioned the conclusion that 0.25 per cent milk was as difficult to purify as 0.5 per cent milk, since the effluents were not of the same quality until they had been aerated four days. The effluents after two days' aeration appeared to be more in conformity with common experience.

Mr. C. Hewitt (Birmingham) remarked that considerable alkalinity must be produced by the breakdown of protein in the beds as evidenced by neutralization of the low pH which followed the initial fermentation and also neutralization of the excess acid produced during active nitrification. It was a matter of interest that substances formed under highly reducing conditions were so readily amenable to oxidation, requiring the assumption that high acidity when produced by bacterial action would be less harmful than when produced chemically. He would like to see a study of the mechanism of the conversion of the deposited fatty material. A similar deposit seemed to occur with sewage during the winter months as indicated by the dry solids content of material attached to the paddle wheel of a traveling distributor which showed 9.68 per cent fat, 6.98 per cent nitrogen, 82.57 per cent organic matter. To what extent the spring flush indicated the effect of temperature on the organism leading to hydrolysis of protein and oxidation of the liberated ammonia, was an interesting problem.

Mr. J. H. Spencer (Northampton) stated he was interested in further information as to the digestion of the solids produced from milk wastes.

Dr. Jenkins, replying to the discussion, stated that dilution with effluent was practiced because the effluent formed a convenient supply of fairly clean water and the question of its superiority to other sources of water had not been tested. He stated that alkalinity for neutralization of acids produced was furnished by breakdown of the proteins. The range in pH values through the plant was about as follows:

	pH
Crude liquid before treatment	6.5–11.0
Crude liquid after storage	5.0– 7.0
Crude liquid after sedimentation	5.0– 6.8
Effluent from primary filters	7.6– 8.2
Effluent from secondary filters	7.8– 8.3
Effluent from activated sludge plant	7.2– 8.1

During the removal of the film from the primary filters when treated with purified effluent, the sludge did not seem to alter much in composition but its physical character changed from a creamy colored slime to a more granular brownish slime.

The sludge produced during treatment of milk wastes was not particularly obnoxious if the wastes were not stored for too long a period. The sludge dried well on beds and could be disposed of on land. Activated sludge rising in the absence of nitrites and nitrates might, he thought, be due to unusually large production of carbon dioxide. He stated that there was probably an optimum concentration of milk, for a given period of aeration, from which a good effluent could be obtained with activated sludge. B.O.D. tests were regularly made on paper-filtered effluents.

R. W. Kehr

STUDY OF THE MECHANISM OF PURIFICATION OF SEWAGE WATERS BY BIOLOGICAL PROCESSES

By F. Dienert

Revue d'Hygiene, 159 (1), January, 1937. Translation by James B. Lackey

In the purification of sewage waters, two simultaneous actions occur; a clarification and an oxidation. Whether one utilizes activated sludge or trickling filters, the same actions are always manifested.

Sewage Waters.—Sewage waters are formed of various organic waste mixed with water. In small villages with no industries the sewer system receives and discharges a

liquid containing principally fecal matters plus additional animal and plant debris from the kitchens. Among the fatty materials a great part is formed of soap. In many villages there is no industrial residue. All these waters contain numerous bacteria and putreseible organic matter which give off bad odors.

Process of Activation.—Strongly aerated, sewage water remains in a state of activity for a certain time, sometimes during 3 or 4 weeks. Then one sees it quickly clarify and on the bottom of the aeration chamber, notes the presence of a dark accumulation more or less of a flocculent aspect.

This residue, introduced in sufficient quantity into new sewage and aerated, clarifies this liquid in some hours instead of several days. The mud or deposit which accomplishes this work, takes the name of activated sludge.

By the measure with which one augments the quantity of sewage added to this activated sludge and according to its aeration one sees its volume (the activated sludge) increase little by little, and according to its agitation the mixture, at the end of purification, gives a clear supernatant after some hours.

Trickling Filters.—The purification of sewage might be accomplished simply by letting it trickle over materials piled in a heap.

During a certain time the effluent issues from these materials turbid and poorly purified. Then one sees the effluent clarify and it is not more likely to give off bad odors than when kept from the air and at a temperature of 30° C.

On the bed of clinkers one remarks the presence of a mucilaginous residue whose presence coincides with purification. The pile of materials, covered with the mucilagenous residue, constitutes what is called the bacterial bed or trickling filter.

Examination Under the Microscope.—Sewage contains solutes, colloids and suspensoids. The suspensoids on microscopic examination are informative. They are more or less yellow brown and mixed with very many bacteria. The activated sludge and the mucilaginous part which one encounters in the trickling filter are composed of different bacteria, filamentous and short rods, which in zooglea constitute a mass with little color and holding on the outside various spores, and sometimes mycelia of fungi with their spores.

On this mass protozoa and amoebae are active.

There is always a difference between the activated sludge and the deposit from the trickling filter. When one agitates the one or the other of these deposits in water, the activated sludge leaves the water clear on settling, but with the second the liquid becomes opalescent; we shall see why in what follows.

Microscopic examination reveals little about the material of the purified sludge. Its study demands the use of other bacteriologic technique shown later.

To arrive at a rational and economic utilization of the purifying activity of the bacterial bed it is indispensable to know its exact mechanism. We will endeavor to show this.

Practical Formation of Activated Sludge.—When one places in operation an installation for activated sludge, it is necessary to aerate the sewage a very long time to obtain a little activated sludge. As the purification of water does not take place rapidly except in the presence of a sufficient quantity of activated sludge (10 to 20 per cent, according to the particular case) one has to aerate a certain quantity of sewage before arriving at the necessary proportion.

It is a long procedure. To diminish the time one might introduce in the sewage a certain quantity of sludge previously recovered by decantation (from a clarifier or catch basin). Experience shows that these muds have undergone the beginning of purification.

Assuming that one has introduced 10 per cent of this mud; in aerating this 2 or 3 weeks, it is transformed into activated sludge and thus one obtains in a short time activated sludge sufficient to purify sewage in only 6–12 hours.

Following this from a chemical point of view, in the first days of aeration the activated sludge forms abundant ammonia which slowly diminishes.

The sludge, examined microscopically, shows a residue which clarifies little by little. The yellow brown tint disappears. Filamentous bacteria and those in zooglea develop.

Study of the transformation of the sludge in the course of activation is best followed on working with other liquids than sewage, especially the waste from a creamery.

To make activated sludge with this, one aerates in the presence of casein, but after having removed most of the lactose. Here the casein replaces the sludge previously introduced into the used water. At the beginning of aeration one sees the casein break up and the water is intensely agitated; a quantity of ammonia appears and the casein residue diminishes in weight. In spite of strong aeration, the liquid has a slightly putrid odor which indicates a great attack on the casein. There is also at first a separation of a certain quantity of phosphoric acid. To make this activation one must add a little sodium carbonate to maintain neutrality. At the end of some weeks of aeration, after having added to the medium a little activated sludge from sewage the liquid becomes clear and brownish.

From this time it is activated sludge and will not disintegrate more.

Under the influence of various bacteria which work simultaneously in the course of activation, the casein has been attacked in such manner that it has resulted in a residue having the appearance of little flocs as those of activated sludge of sewage, but the color is different; it is yellowish instead of black-brown.

One can not compare the transformation of this casein to that obtained with certain bacteria which secrete casease and bring casein completely into solution. There is in this case decomposition of the casein, a partial oxidation of it, and the formation of a residue insoluble and difficult to attack.

The activated sludge and the casein so transformed are in reality a support to bacteria. Is this support necessary, and under what conditions?

It was shown that while in the activated sludge of sewage there existed ciliated protozoa, they had not been found in the casein activated sludge. It is now shown that the first effect of bacterial action in ordinary activated sewage sludge is a breaking-up brought on by the aerobic bacteria and in consequence, the absorption of oxygen.

The breaking-up is variable according to the importance of aeration. If the quantity of oxygen is insufficient, the bacteria which develop secrete liquefying diastases, rendering the liquid opalescent. This occurs in the trickling filter throughout when aeration is incomplete and it is one of the principal causes of the opalescence shown above on agitating the sludge of the trickling filter with water. The materials in suspension in sewage favor the formation of the sludge but for their transformation, a bacterial action which demands a certain quantity of oxygen is necessary. If the aeration should be insufficient, trouble will ensue in purification because there will not be enough air for all the bacteria which oxidize the organic matter dissolved and in suspension. The particles of organic matter in suspension are transformed but at the expense of the dissolved organic matter. Suppress this transformation of the suspended solids and the second can be oxidized with less air. The activated sludge ought to settle rapidly when one decants it. Unhappily certain filamentous bacteria develop at times in the sludge, rendering it voluminous and very much charged with water. This is the phenomenon of "bulking." The sludge then settles very badly and with very great slowness. The effluent is not clear and one may generally note this poor condition of the sludge in the effluent as due to certain residual waters containing sugar material. The presence of these materials favors the secondary action and hinders the purification of sewage water.

With milk wastes we have never found this inconvenience. We remarked in the beginning that activated sludge is more difficult to digest than the primary sludge, that is why it is necessary to make it in the least possible time. Activated sludge is useful for purification but it presents certain grave inconveniences and to avoid these one must diminish its importance but perhaps still use it.

Study of the Mechanism of Biologic Purification of Sewage.—Activated sludge is a mixture of many bacteria with organic matter. Oxidation of organic matter and precipitation of colloids are the results of bacterial action. Chemical phenomena that occur are wholly due to bacteria, which are the only catalyzers here. To our mind it has not been demonstrated that the colloids of sewage can serve as chemical catalyzers, as the following work will show. The fundamental work on which we plan our demonstration is the following:

If one sterilizes sewage, deprived of suspended matter, and then inoculates it with

a platinum needle touched to activated sludge; it clarifies in some days at 25° C., free of organic putrescible matter.

In this one does not need to bubble air through. There is enough aeration from the air overlying the surface of the liquid. It is only necessary to place it in a flask, having a large surface area exposed. In the bottom and on the sides, one can see a short time after the inoculation a thin pellicle enclosing the colloidal matter. This pellicle becomes partly detached and gives place to a yellow brown deposit appearing like activated sludge. This sludge inoculated into sterile sewage, accelerates its purification, which can be obtained in less than 24 hours. The sludge thus obtained is then sterilized. If one inoculates sterile sewage with it, no clarification or oxidation of organic matter results. To return to this sludge its activity, it suffices to inoculate it as before, with a platinum needle. This experiment, extremely simple, has to my knowledge, never been reported. It shows beyond debate that clarification, oxidation and breaking down of organic matter in sewage are the exclusive work of the bacteria.

Relative to the oxidation of ammonia the work of Winogradsky has shown clearly the presence of numerous bacteria (ferments) of nitrification in activated sludge.

In the fundamental work shown above it is demonstrated that the oxidation of ammonia has not taken place until after inoculation.

To continue this study I made an artificial sewage of constant composition to enable me to better follow the mechanism of purification.

Artificial Sewage.—One takes 100 gms. of sludge from a catch basin with 1,000 c.c. dist. water. Triturate the sludge with this in a mortar. Centrifuge the blackish water to throw out suspended matter. Sterilize the liquid. This leaves a precipitate. Centrifuge again, sterilize the liquid a second time. The liquid thus obtained has a sufficiently constant composition to be little changed. It deposits, little by little, however, carbonate of lime which can be eliminated by aseptic decantation of the liquid.

Sometimes in several of my experiments this deposit has shown one of the mechanisms of clarification as shown by the following.

This liquid (the sterile activated sewage) inoculated with a drop of sewage reduced methylene blue in less than 12 hours; inoculated with a trace of activated sludge the liquid purified and did not reduce methylene blue in 5 days.

Microbiologic Study of Activated Sludge.—When one wishes to isolate the clarifying or oxidizing bacteria by usual bacteriological methods (inoculating onto agar, peptone or peptone gel) no result generally is obtained. The bacteria isolated do not clarify sewage or form zooglea. Certain known bacteria as *B. subtilis* oxidize the organic matter.

When one might wish to study the bacteria of activated sludge, one inoculates then into a given volume of sewage. This is divided into a large number of tubes, after the fashion of obtaining bacteria isolated in the medium in which they live. To divide the sludge, place it between two sterile slides and roll one on the other, which divides the sludge well. One might by this method study the development of useful germs.

The bacteria thus isolated might be purified if to the sterile slide a little previously sterilized sewage is added, or by using agar in which peptone is replaced by 1 per cent sewage. Adding cellulose facilitates their proliferation.

C. T. Butterfield of the Public Health Service at Cincinnati has employed another method. He washes activated sludge 10 or 12 times in sterile water. He finally obtains a zooglea whose bacteria cannot live on peptone agar but multiply in peptone water or sterile sewage. This method of isolation might be replaced by the following: Place activated sludge in a large crystallizing dish, exposed to air, with a little water. There will develop little by little on the surface white colonies forming little veils which hang to the surface. These are washed first in sterile water then in water to which 2 mgms. of chlorine per liter is added, so as to kill off a certain number of bacteria mixed with them. Cultivated in sewage this colony in the zooglea forms a residue like activated sludge.

There are in this sludge bacteria which clarify, and bacteria which oxidize and reduce. To get a purer strain of bacteria for clarifying sewage, leave them in an open dish for several weeks. At the end of a certain time, the water clarifies, and in the bottom of the dish zoogleal bacteria are found. These are washed with sterile water and

in sterile sewage they develop freely, clothing the sides of the vessel with a fine veil. Clarification of agitated sewage is obtained in several hours. These bacteria are isolated in the same manner in which one obtains bacteria of activated sludge.

Mechanism of Purification of Sewage.—We have shown above that the bacteria form a deposit on the sides of the glass. When one introduces into the trial tube containing sewage, sterile glass rods, very small, the bacteria settle on the surface of these. One can then withdraw and wash these bacteria to obtain some degree of purity.

Action of Bacteria Obtained From Activated Sludge.—It is really very difficult to isolate completely the bacteria of activated sludge because the zoogleal bacteria entrain, in their colony, different bacteria which cannot be separated from the mucilaginous mass.

Most of the bacteria oxidizing sewage are small coccus forms surrounded by an envelope which is the zooglea. They do not stain with Gram stain, do not ferment sugar. Some are ciliated (Butterfield). These partly clarify sewage. Complete clarification is obtained by a symbiosis of microbes, and among these it is necessary that there be on the zooglea protozoa, monads (= flagellates?) and a sort of large coccus but slightly motile, which will not develop well except in the presence of the zooglea.

In all attempts we have only rarely isolated by our methods nitrifying ferments but have seen the disappearance of NH_3 without the formation of HNO_3. This problem is left for another time.

The symbiosis of the bacteria seems to be necessary for vigorous action.

Oxidation, reduction and clarification might be accelerated by mixing different species of bacteria, and insofar as one can break up the zooglea to obtain purer strains of bacteria, one can say the oxidation and clarification can be further refined.

Clarification of sewage is considerably decreased after one flattens the sludge between glass plates. Sewage is rapidly and completely clarified with sludge not so confined. This flattening destroys the large coccus, a kind of monad which appears to be a germ indispensable to clarification, but which has not been obtained in pure culture. It does not seem to live without the zoogleal bacteria.

These 3 types of bacteria isolated (clarifying, oxidizing, reducing) form the film. They are strongly attached to the sides of the culture dishes. They enclose all the particles in suspension in the liquid and one notes in the interior of the film particles of lime carbonate which were deposited in the bottom of the tubes or flasks.

It is the development of these bacteria which forms the activated sludge proper.

Before their development, in a tube for example, one sees on agitation very fine particles in suspension. When the zooglea develops all these are agglutinated in the zooglea. Agitation returns large floes to suspension but not fine particles. Aeration must be thorough for this. If insufficient not all particles are agglutinated. This is what goes on in the trickling filter where oxidation is less thorough than with activated sludge. When one agitates this, one returns to suspension the particles which have not been sufficiently agglutinated in the zooglea.

Variation of Oxidizing and Clarifying Bacteria in the Course of Activation.—When sewage is activated, one notes at the beginning, (1) the clarifying bacteria are few, and (2) the oxidizing bacteria are also rare.

But these are two kinds of completely different bacteria. One can obtain purified water but not clarified, or clear but insufficiently purified. The clarifiers do not completely oxidize the organic matter.

Mechanism of Purification of Sewage.—Multiplication of these germs is very slow when organic matter is too concentrated in the liquor. This organic matter is transformed and degraded by proteolytic bacteria.

By experiment we have determined what was the quantity of peptone to introduce into sewage inoculated with clarifying and oxidizing bacteria which hampered their action. This was about 1 gm. to a liter. If we take out the suspensoids, leaving only the colloids, oxidation and clarification proceed more quickly. Instead of aerating 15 days to 3 weeks to get activated sludge it appears on the sides of the vessels or the glass rods in 5 days.

Activation seems to manifest itself when putrescible matter has been transformed, for it can not then harm the oxidizers or clarifiers who are very susceptible to its influ-

ence; however these organic matters are transformed, the clarifiers and oxidizers augment rapidly. Their count shows this rapidity:

After 2 days activation about 10 bacteria;
After 5 days activation about 100 bacteria;
After 12 days activation about 10,000 bacteria;
After 15 days activation about 1,000,000 bacteria.

These counts were made from 1 c.c. of sludge taken after settling 1 hour. Oxidation was determined by titration of organic matter with permanganate.

In the absence of suspensoids, increase of these bacteria is clearly much more rapid.

Activated sludge to us then, is a culture of bacteria forming zooglea and film. In the interior of the zooglea other microorganisms such as Leptothrix grow; also the protozoa which work on the organic matter and transform it more or less rapidly. Complete study of the bacterial action of these sludges is made difficult by the fact that the organic matters oxidizable and having a nature very variable and indeterminate, are attacked by different bacteria. One notes often that the symbiosis is momentarily suspended by the disappearance of some microbial species.

Conclusions

This first study of the action of activated sludge on sewage shows that is is really formed for the greater part of oxidizing and clarifying bacteria living in symbiosis in zooglea which bring down and oxidize suspended and colloidal organic matter.

Action of the clarifiers and oxidizers is hindered by the organic matter in suspension. One augments their activity by previously freeing the water of these organic matters in suspension which withdraw, after a fashion, the unused oxygen that might facilitate the action of the oxidizing bacteria.

In studying the phenomenon of biologic purification of sewage one notes that in reality the well constructed bacterial bed provides the best condition for purification.

The upper part produces a filtration. Organic matters in suspension are arrested, and below, water deprived of these materials is in contact with oxidizing bacteria who purify it in a minimum time.

It is remarkable that if with activated sludge 6 to 8 hours are required to purify sewage, it requires less than 1 hour with a bacterial bed (trickling filter) to obtain the same purification.

This shows that considerable changes might already be caused in purification by the oxidizing bacteria.

James B. Lackey

REPORT OF THE SPECIAL COMMISSION ON THE INVESTIGATION OF THE DISCHARGE OF SEWAGE INTO BOSTON HARBOR AND ITS TRIBUTARIES

December, 1936, House Document No. 1600, Commonwealth of Massachusetts, 332 pp. and insert maps.

This is a report made by a Special Commission, composed of the Massachusetts Commissioners of Public Works, Public Health and the Metropolitan District Commission, together with the Boston Commissioners of Health and Public Works, covering the discharge of sewage into Boston Harbor. This subject has been investigated a number of times, notably in 1900, 1917 and 1929–30. Each time, the main sources of pollution shown were the main sewer outlets of the Boston Main Drainage System (1877–1884), the North Metropolitan System (1889–1894), and the South Metropolitan System (1899–1904). The Boston Main Drainage discharges at Moon Island, from storage tanks, preferably on the second and third hours of the outgoing tide. The North Metropolitan discharges through multiple outlets near Deer Island Light. The South Metropolitan discharges at Nut Island.

In 1935 a population of 1,833,160 contributed sewage to these systems. In no case

is serious depletion of dissolved oxygen noted in the main harbor waters, which would result in objectionable conditions, but areas of sleek and objectionable floating matter are found which affect the shores and bathing. A restricted local condition not so satisfactory within Boston proper is probably caused by excessive storm overflows. There depleted dissolved oxygen was noted. Certain areas are affected so that bathing has been stopped. Boston Harbor is actively used for recreation, there being 21 yacht clubs around its shores, with 29 established bathing beaches, of which 14 are under public control. Probably 5,300,000 use these beaches along the Boston water front. The survey emphasizes the necessity of limiting bathing to sites developed under proper sanitary supervision, to avoid bathing too near to sewer overflows. The taking of shellfish from much of Boston Harbor for food was prohibited as far back as 1906. As yet, however, the discharge of sewage into Boston Harbor has not caused conditions dangerous to the public health.

A very comprehensive engineering report is included, prepared by a Board of four engineers and the Deputy Commissioner of Health of Boston (respectively, Messrs. A. D. Weston, John N. Ferguson, Joseph P. Dever, George W. Dakin and Dr. M. V. Safford). This reviews the history and present status of the sewerage problem of the Boston Metropolitan area, with details of observations on currents, bacterial concentration and dispersion of sewage. At no point (except in Fort Point Channel) was the dissolved oxygen below 57 per cent saturation. Consequently, the engineers conclude the great dilution possible in Boston precludes the use of a high degree of purification. Some form of pre-treatment to remove grease and floating matter is recommended, or so-called preliminary treatment. For this purpose, the various forms of treatment available are considered, including grit chambers, storm water tanks, rack or bar screens, fine screens, skimming tanks, sedimentation, chemical precipitation, rapid filtration and chlorination. The disposal of screenings and sludge is discussed, by digestion, filtration, incineration, spray drying, centrifuging, and disposal at sea.

Small scale experiments were made at the three main outlets. The average raw sewage analyses were:

Results in Parts per Million

	Boston Main Drainage		North Metropolitan		South Metropolitan
	Calf Pasture 1935	Moon Island 1936	Deer Island		Nut Island 1936
			1935	1936	
Susp. Solids	162	119	256	148	156
B.O.D	157	144	249	175	119
Kjeldahl N.	9.1	8.6	16.4	11.2	9.6
Oxygen Cons.	53	50	81	69	50
Alb. Amm.	4.1	—	7.5	5.3	3.7
Free Amm.	21.5	18.1	34.1	24.4	20.3
Chlorides	4,080	3,478	3,280	3,151	198
Fats	50	34	83	41	49

The total amount of sludge from the three outlets daily is estimated at 80 tons dry solids, or 13,530 cu. ft. at 80 per cent moisture, or 405,000 gallons at 95 per cent moisture.

At the Boston Main Drainage test, plain sedimentation for two hours removed about 40 per cent of the fats by skimming, with 51 per cent removal of suspended solids, and 19.3 per cent reduction of B.O.D. With six hours detention, 62.5 per cent of the suspended matter was removed, 34 per cent of the B.O.D. and 58 per cent of the fats. The removal of fats was not materially increased by pre-aeration. However, with 2¼ hours detention, 57 per cent of the suspended matter was removed. Slightly better removals of

suspended matter and B.O.D. were obtained on the North Metropolitan. On the South Metropolitan, even better removals of suspended matter and B.O.D. were obtained.

Plain Sedimentation Results with 2-Hour Detention, Percentage Reduction

Outfall	Main Drainage Calf Pasture	North Metropolitan	South Metropolitan
Suspended Matter	50.9	51.4	69
B.O.D.	19.3	24.6	40
Kjeldahl N.	21.9	32.8	40
Oxygen Cons.	25.0	18.3	36
Fats	39.1	42.9	50

Fine screens with 1/16- to 1/8-inch openings were also tested.

Screenings Caught, Dry Pounds per Million Gallons

Size of Screen Inch	Main Drainage Calf Pasture 1935	North Metropolitan		South Metropolitan 1936
		1935	1936	
1/16	106	75	108	75
3/32	92	59	52	52
1/8	83	—	33	47.7

The removal of suspended matter by the screens ranged from 3.6 to 7.5 per cent.

The use of pre-aeration to aid in grease removal was not successful.

Large scale tests were made continuously at Moon Island on one of the storage tanks, with a detention period ranging from 1.7 to 5.8 hours, averaging 2.8 hours. The removal in per cent was 56.7 for suspended solids and 25.6 for B.O.D.

The engineers recommend continuing the policy of excluding surface water, storm water and infiltration from sanitary sewers in the various districts. The control of bathing beaches is also recommended. When the time comes for treatment, partial treatment should suffice. The estimated first cost of the three works is around $14,470,000.

The report is an important and up-to-date presentation of the problem of sewage disposal in a tidal water, and is a welcome addition to the sanitary engineer's library.

LANGDON PEARSE

THE WORKS OF THE BIRMINGHAM, TAME AND REA DISTRICT DRAINAGE BOARD

Pamphlet issued by H. C. Whitehead, M.I.C.E., Chief Engineer, dated July, 1937. 89 pp. Illustrated.

This issue brings up to date the history of the Board's Works issued in 1931 (Cf. *This Journal*, **4**, 207 (Jan., 1932)). The Board serves an area of 103,378 acres, with an estimated population (April, 1937) of 1,256,400. The present sewage flow is 55,813,000 U. S. gal. per day, or 45 gal. per cap. per 24 hr. In addition to the main works, six temporary works are operated. The analyses of the sewage and effluents for 1936 are as follows in p.p.m.

Raw Sewage

Plant	Susp. Solids	Free Amm.	Alb. Amm.	Cl.	Oxygen Absorbed		Alk.
					Unsetld.	Setld.	
Barston*	179	33.2	7.8	48	51.9	29.7	214
Coleshill*	173	32.2	7.3	78	49.5	29.0	259
Rea and Hockley	439	25.7	7.2	163	207	151	119
Aston and Handsworth	295	28.1	7.3	78	114	87	146
Saltley	604	23.1	7.5	107	211	128	49
Yardley	362	33.0	9.3	80	129	83	113

* Rated as domestic.

The main works employs primary (covered) and secondary settling tanks at Saltley, giving 12¾ hr. sedimentation ahead of the biological treatment at Minworth (4½ miles away). Some 400,000 tons of sludge per year are arrested, containing 92 per cent moisture, and digested at Saltley, about 28 per cent by weight of the solids being converted into gas (29.6% CO_2, 69% methane, and 1% N). The temperature of digestion is controlled. Gas collected (B.T.U. 635 per cu. ft.) is used for generating power in gas engines, the circulating water being used by heat exchangers to warm the sludge. After a primary digestion of one to two weeks, the sludge is pumped to Minworth for secondary digestion. The sludge is finally dried to 35 per cent moisture on outdoor beds, yielding some 60,000 tons of dried material per year. This results from 600,000 tons of crude sludge, a reduction by weight of 90.55 per cent. The digested sludge contains 52.8% ash and 2.47% nitrogen.

During warm weather, 10 p.p.m. of lime is added to the primary sedimentation tank effluent and 3 or 4 p.p.m. of bleaching powder to the secondary tank effluent.

Spent gas liquor (about 875,000 gal. per week) is discharged to the Saltley Works by a separate pipe and equalized by storage.

At Minworth, bio-flocculation is followed by trickling filters. In one bio-flocculation plant handling 12.5 million gal. settled sewage per day, paddle wheel aeration is used for one hour on the liquid, the sludge being reconditioned separately. The second bio-flocculation plant uses diffused air on a one-hour period. The workings are as follows:

	No. 1	No. 2
Daily Flow of Sewage, Gal.	12,000,000	15,000,000
Ratio of Volume of Activated Sludge to Sewage	1 to 6.6	1 to 8.3
H.P. per mil. gal. sewage per 24 hr.	10.5	8.16
Volume of Settled Sludge in Conditioning Tank (18 hr. Settlement) Per Cent	11.0	13.0
Dry Weight of Sludge in 100 cc. Conditioning Tank Sludge (Shaken sample) gm.	0.173	0.313
Dry Weight of Sludge in 100 cc. Conditioning Tank Sludge After 18 hr. Settlement. gm.	1.57	2.41
Loss in Ignition of Dry Sludge Per Cent	70.4	72.4

Mr. Whitehead states in a letter that the period of re-aeration of the sludge is 8.6 hours where diffused air is employed and 13.5 hours where mechanical agitation is used.

The only analytical results given are as follows, for the major plants at Saltley and Minworth:

Average Results for 1936

	Results in P.P.M.						
	Susp. Solids	Free Amm.	Alb. Amm.	Cl.	Oxygen Absorbed		Alk.
					Unsetld.	Setld.	
SALTLEY:							
Raw Sewage	604	23.1	7.5	107	211	128	49
Secondary Tank Effluent	37	43.2	6.9	137	105	101	218
Sedimented Liquor Leaving Saltley	42	28.2	5.6	132	123	118	149
MINWORTH:							
Bio-flocculation Effluent	20	43.0	6.0	137	79	77	222
Bacteria Bed Effluent (Blocks E & F)	26	27.1	2.0	137	21.1	17.8	139

Oxidized nitrogen in the bacteria bed effluent is reported at 13.2 p.p.m.

Blocks E and F have traveling distributors.

At Minworth are 43 acres of bacteria beds, 6 to 7 ft. deep, with 1 to 2 inch material. In dry weather, recirculation of an equal quantity of effluent is found desirable for that portion of settled sewage not receiving bio-flocculation treatment. To keep down the fly nuisance, common salt has been applied at the rate of 2 tons per acre, or a 5 per cent solution of gas liquor is applied.

Excess activated sludge and humus sludge are concentrated in tanks to a solid content of 3.09 per cent. The dry solid content of Minworth sludge is 25 per cent of that deposited in the primary sedimentation.

In 1934, the first unit of five for the Coleshill Works was completed, on a site of 120 acres. This is part of a regional scheme of sewage and sewage disposal, for about 50,000 population. The first unit is designed for 67,000 population and a flow of 2.4 million gallons per day. All the power required is obtained from gas from sludge digestion. The secondary and aeration tanks are designed to balance the variable dry weather flow. Between the primary and secondary sedimentation tank is placed a pre-aeration tank supplied with excess activated sludge. This aids sedimentation. Storm water tanks are provided of capacity equal to 12 hr. dry weather flow. The primary settling tanks have a capacity of 4 hours dry weather flow, and can handle up to three times the dry flow. The secondary sedimentation tanks have a capacity in dry weather between 8½ and 11½ hr. period. The aeration period is 1 hour. The diffusers are removable, set in cast iron boxes. The final settling tanks are on a 4-hour period.

In the year ending March 31, 1937, the daily average flow was 3.3 mil. gal. The total air used was 0.49 cu. ft. per gal., of which 0.04 was for pre-aeration. The percentage by volume of activated sludge circulating was 24.6 in the aeration tanks and 1.9 in the pre-aeration. The horse power per million gallons of sewage treated was 14.2 and 18.8 per million gallons of dry weather flow per 24 hr. The gas yield per cap. per day was 0.78. Of 17.1 million cu. ft., 4.2 million were discharged to the atmosphere. Digestion temperatures varied from 64 to 74 deg. F., averaging 69. The crude sludge to primary digestion contained 95.6 per cent water. The volatile matter on a dry basis was 74.7 per cent in crude sludge and 51.2 per cent on digested. For digestion the five primary tanks give a period of 50 days; the three secondary tanks add 31 days. Moving gas collectors are used. Four acres of sludge drying beds are provided. The works cost £144,000, or approximately $720,000.

The works of the Board have cost to date £2,507,962, of which £1,596,706 has been repaid. The annual charge for the Board's work in 1937–38 is estimated at £205,278, or 3s 3½d per capita (approximately 82 cents).

The report is an interesting document, describing outstanding works, with novel features, quite different from U. S. practice.

In answer to an inquiry, Mr. Whitehead wrote the reviewer as follows:

The sludge digestion capacities are as follows:

Tame Valley Works	8	cubic feet per capita
Coleshill Works	3	cubic feet per capita
Yardley Works	2.6	cubic feet per capita

At Coleshill there is no trouble with a high water content of the sludge as, although the average per cent moisture entering the primary digestion tanks is about 94, it is possible (by employing two-stage digestion) to reduce the water content to approximately 92 per cent.

At Yardley a smaller digestion capacity is employed as the bulk of the gas is available for heating, and it is usual to maintain a temperature between 75 and 80° F., whereas at Coleshill the average temperature is only 69° F.

The comparatively large digestion capacity in the Tame Valley Works is required because the sludge there contains a large amount of trade waste, which has the effect of lengthening the period needed for digestion; also the tanks are of earlier and of less efficient design than those at Coleshill and Yardley, and only a third of the total capacity is heated to the small extent of 10° F. rise in temperature.

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